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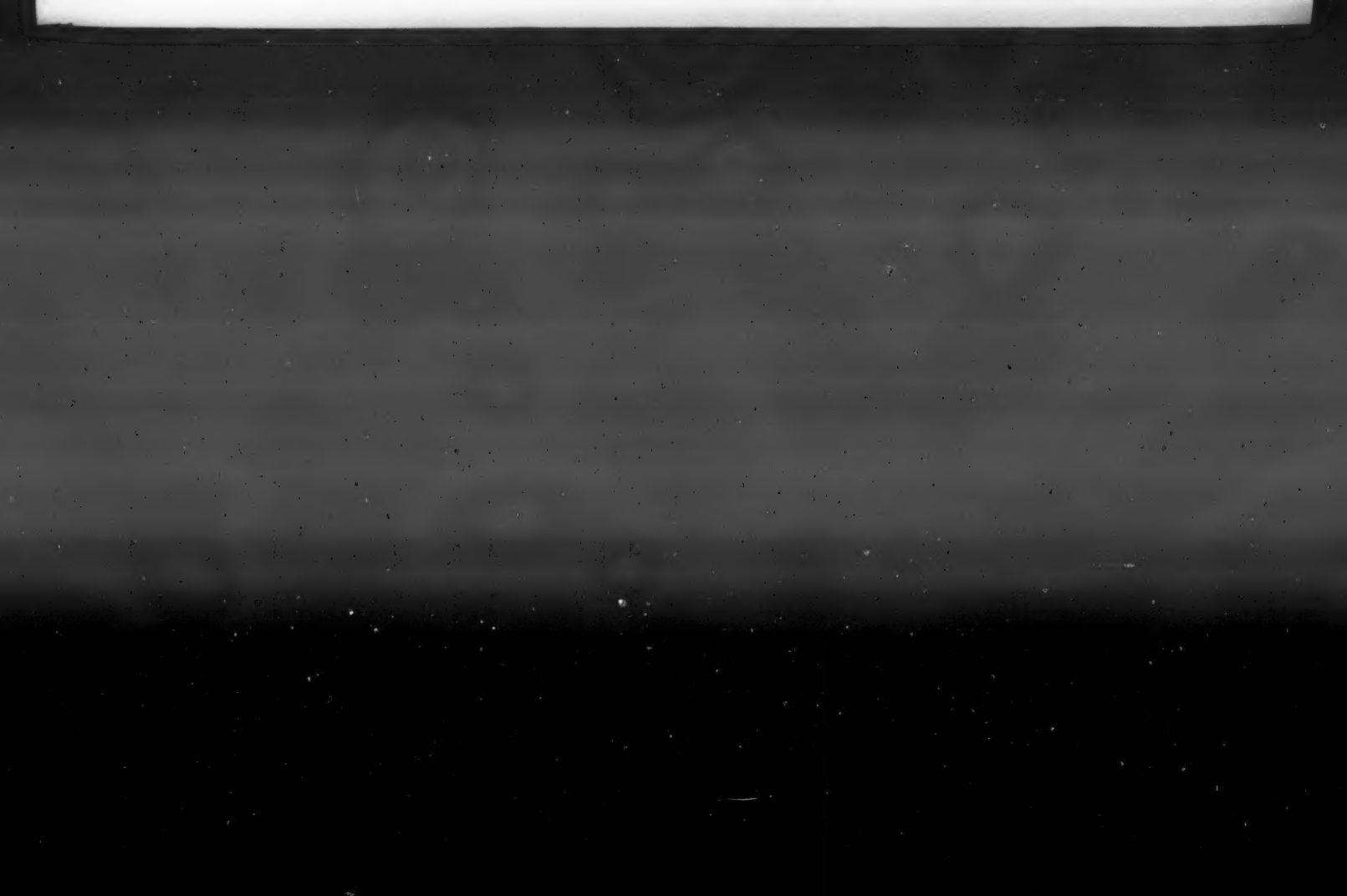


THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXVIII.—*On Allotropic Silver;* by M. CAREY LEA.

Part II.—Relations of Allotropic Silver with Silver as it exists in Silver Compounds.

THE first part of this paper* was devoted to the examination of one of the well marked forms of allotropic silver,—the gold-colored. The blue form in its soluble and insoluble varieties will be more particularly described in a future paper. The subject at present to be considered is the relation existing between the allotropic forms of silver taken generally and silver as it exists in its compounds and more especially in the silver haloids.

It is a well established law that when a substance is capable of existing in two forms, of which one is a polymer of the other, the polymeric form possesses greater density and less chemical activity. Combination is usually accompanied with loss of activity, and the polymerization of a body consists in its combination with itself. When a substance is capable of existing in two allotropic forms and of being converted from the one to the other by pressure, the body resulting from pressure is always the more dense of the two and is a polymer of the first.† In the case of allotropic silver these laws appear to be verified. I have shown elsewhere that gold-colored silver has a specific gravity of 8·5, while that of normal silver is 10·5 to 10·6. The greater chemical activity of the gold-colored form is demonstrated by its greater affinity for oxygen, sulphur and

*In the March number, pp. 179–190.

† See examination by Spring of the effect of pressure, Ber. D. Ch. Ges., xvi, p. 1002, 1003.

the halogens. Also it is conspicuous by the remarkable facility with which it passes from the one state to the other. Spring, in the examinations above referred to, used pressures of many thousands of atmospheres. Allotropic silver is changed readily to normal by the mere pressure of the finger or by a temperature of 100° C.

One form of allotropic silver has the property of solubility in water. The solution of a solid in a liquid is often accompanied by change to a more simple molecular structure. Hitherto the only solvent known for a metal has been another metal, and the behavior of metals when so dissolved has been the subject of late years of very interesting examinations by several chemists. Ramsay* examined the lowering of the vapor pressure of mercury by other metals dissolved in it. Heycock and Neville examined the fall in the freezing point of metals, more especially of tin, caused by the solution in it of other metals.† Both of these investigations led directly to the conclusion that in the case of a dilute solution of one metal in another, the dissolved metal existed in the atomic form. (In each case a few metals gave exceptional results, but silver was not among these.) Tammann's investigations on the alloys of mercury led to precisely similar general deductions. Great weight attaches to conclusions supported in these several ways.

The fact that a metal in dissolving in another metal appears to assume the atomic form affords no positive proof that it does the same in dissolving in water. In fact the solution of a metal in water is something so new that we have little ground for argument by comparison. So far, however, as the above mentioned analogy may be considered to go, it rather tends to the view that the solubility of silver may be due to its having assumed a very simple and perhaps an atomic form. It may be said therefore that all considerations tend to show that the allotropic forms of silver taken as a whole have a more simple molecular nature than what I have described as the intermediate form, and that this again is more simply constituted than ordinary silver.

In the present case we have to consider three distinct forms, (1) allotropic, (2) intermediate, (3) ordinary silver. We notice that (1) can with the utmost facility and in several ways be converted into (2) and (3), and that (2) can always be converted into (3), but that *these transformations can by no possibility be reversed.* To convert ordinary silver into allotropic we must as a first step dissolve it in an acid: that is, *convert it from a polymerized to an atomic form*, and only from this atomic form can allotropic silver be obtained.

* R. Trans., 1889, p. 521, also Wiedemann, Referate 1889, p. 993.
† Jour. Chem. Soc., 1890, p. 376.—Nature, Jan. 1891, p. 262.

Bearing this capital fact in mind and considering the respective properties exhibited by the three forms of silver, it may be allowable to adopt as a working hypothesis the view that they may represent the three possible molecular forms of silver, viz: *atomic, molecular and polymerized.*

As silver in its compounds and in its saline solutions exists in the atomic form, it is easily conceivable that when it separates from such solutions by reduction, the atoms may or may not unite to molecules. Usually elementary atoms do so unite, but the phenomena of nascent action indicate that this union does not take place at the instant of separation, and it is at least conceivable that under particular circumstances this union may be prevented. In some cases no such union takes place. At least four metals exist in the form of vapor in the atomic state. Whether this state continues after condensation we do not know, but there is no impossibility but what such may be the case. Similarly allotropic silver may represent an atomic form: if this were so it should exhibit more active affinities for oxygen and the halogens than the ordinary form; also it should readily pass into the ordinary form. And these properties are undoubtedly exhibited by allotropic silver.

There is no branch of chemical statics in which our knowledge is so defective as it is in relation to the molecular constitution of solids and more especially of the metals. All that can be said is that in metals, as we ordinarily know them, this constitution is probably very complex, the molecules containing many atoms. When substances assume a variety of forms differing from each so much as do the forms of silver, we must either adopt a theory of the character now suggested or else we must suppose that the different forms are differently polymerized. To decide which is the most probable of these two views it is best to examine as to whether an analogy can be traced between these allotropic forms of silver and silver where it is known to exist in an atomic form, namely, in its compounds. For this comparison the silver haloids (and chiefly silver chloride) will be taken.

Action of Forms of Energy on Silver Haloids. Parallelism with Allotropic Silver.

It is a familiar fact that certain forms of energy, light especially, affect the silver haloids. In view of what has been already said as to the action of all forms of energy on allotropic silver, it seemed desirable to make a general examination as to their action on the silver haloids and thus to determine how far a parallelism could be traced.

It is to be observed that the action of different forms of energy on the silver haloids is apt to be partial: the influence seems to be antagonized by opposing and almost equally matched forces. Thus in the case of light, its tendency to condense the atoms of silver to molecules is largely counteracted by the strong affinity of chlorine for *atomic* silver. The action of high tension electricity as will presently be seen is similar to that of light in that it produces a visible effect. In the case of heat and of contact action on these silver haloids, it will be shown that there is at first a mere indication of effect, invisible to the eye, but readily brought out by the action of a reducing agent, as described below. The action of each form of energy seems to be almost counteracted by apposing affinities. But in every case action does take place and *always in a direction corresponding to the action of that form of energy upon allotropic silver.*

High tension electricity it is well known impresses sensitive films of silver haloids, which on development exhibit remarkable ramifications. When electric sparks are passed through paper on which a coating of silver chloride has been made, the point of passage of each spark is marked by a minute circle of violet color indicating a visible change, probably to a subchloride.

Mechanical force.—More than twenty years ago I noticed that by a slight pressure, an invisible effect, capable of development, could be impressed on silver iodide. Lines drawn with a glass rod or any other hard, neutral substance were reproduced. An embossed card pressed gently on the film, gave an image of all its details on development. These experiments were extensively repeated by others with concordant results.

I have recently repeated them with silver bromide with similar effect.

Heat.—To determine the effect of heat on silver bromide, pieces of bromide paper were placed in a desiccator (of course using inactive light) and heated to the extent indicated. For each piece so heated, a corresponding piece cut from beside it in the same sheet was preserved, and these two pieces, that heated (after complete cooling) and that not heated, were placed side by side in an oxalate developer. Comparison between these developments indicated the effect of the heat. The following results were obtained.

A piece kept for 3 minutes at 145° C. was strongly affected and blackened quickly in the developer, the companion piece remaining white.

A piece kept for 15 minutes at a temperature commencing at 131° C. and ending at 136° was still more thoroughly affected than the foregoing, the longer exposure more than making up for the lower temperature. Companion piece remained white.

A piece kept for 8 minutes at a temperature 107° to 108° was distinctly but not strongly affected. Companion piece as before.

A piece kept for 17 minutes at a temperature of 100° to 102° was almost unaffected. A long and careful development brought out a faint difference between the piece so heated and its companion piece.

It was found that to obtain accuracy in determinations such as these, the paper must rest on a glass, and not a metal, shelf in the desiccator, as the metal shelf is always hotter than the air by which the thermometer is affected. In using a metal shelf, if the paper curled by reason of the heat, the part that rested on the shelf developed darker than that which was simply acted on by the air. By substituting a glass shelf this difference of effect disappeared.

The result of the foregoing and other experiments was that the effect of heat on AgBr commences at about 100° C., that up to 108° it is still slight and acts slowly, but that at 120° to 126° a strong action commences, which further increases as the temperature is raised. The analogy with allotropic silver is well marked.

It may at first seem strange that a temperature of 100° C. should produce a permanent change in a substance which will bear a high heat without decomposition, but the explanation lies in the presence of water in the former case. When silver bromide is formed in paper and dried in the air it still retains moisture. Even at 100° C. this moisture is not driven off. A silver haloid requires to be heated to a temperature between 130° and 140° for several hours before it ceases to lose weight. Therefore in all the foregoing cases moisture must have been present.

It remains to be shown that by a sufficiently long exposure to a moderate heat in the presence of moisture a visible decomposition results.

For this purpose silver chloride was precipitated with an excess of hydrochloric acid, after thorough washing was placed in a glass tube of about a centimeter in internal diameter and one-half a meter long, and was sealed up with a blast lamp. During all these operations the chloride was thoroughly protected from light. Five of six cubic centimeters of pure water were first added to the chloride. It was intended to exclude completely or almost completely the effect of pressure and to act on the chloride as far as possible by heat only, and for this reason a longer tube was used and one end only was immersed in the chloride of calcium bath, the other end remained cold throughout the operation.

The silver chloride formed itself into a compact plug and was forced by the steam which generated below it up to the

middle of the tube. This effect, though not intended, answered very well as the chloride was kept constantly under the influence of steam at about 100°. It soon began to darken and at the end of three or four hours all the lower part was violet brown, the upper part gray, the change taking place entirely through the mass. Some thin smears of silver chloride on the lower inside part of the tube were completely blackened.

On opening the tube next day there was no escape of gas. The water sealed up with the silver chloride had acquired a faint but distinct alkaline reaction showing that enough alkali had been dissolved from the glass to overcome any acidity arising from decomposition of the chloride. The water contained traces of alkaline chloride.

A similar examination was made with silver bromide precipitated with excess of hydrobromic acid and thoroughly washed with distilled water. The action of diffuse light on silver bromide is very different from that on silver chloride. A portion of that prepared as above mentioned changed in diffuse light very quickly from yellow to greenish yellow, but after that first change the alteration was extremely slow and in an hour had only reached to a dirty greenish gray. The action of direct sunlight was quite different; fifteen minutes' exposure changed the greenish gray to dark chocolate brown.

In the tube the silver bromide did not form a plug like the chloride but separated into balls which remained in the bottom of the tube. By keeping the chloride of calcium bath considerably above 100° C. the water in the tube was kept actively boiling: it condensed in the upper part of the tube and returned. Six hours of this treatment only brought the bromide to the same greenish color which it would have acquired by a few minutes' exposure to diffuse light.

The conclusion to be drawn as respects both the silver haloids is that they undergo actual decomposition by the action of moist heat, but that this effect is much more marked in the case of chloride than that of bromide.*

Chemical action.—Dilute sulphuric acid quickly changes allotropic silver to normal, and therefore if the parallelism which I have indicated really exists, marks made on bromide paper with dilute sulphuric acid should be capable of development.

The experiment was made by drawing characters on silver bromide with a glass rod dipped into sulphuric acid diluted with twice its bulk of water. After allowing the acid to

* Light and heat act differently on silver chloride Heat can not decompose it in the absence of moisture but light can. This was proved by an investigation made by the writer in 1889, in which it was shown that fused silver chloride poured into petroleum and exposed after cooling to the sun's rays was instantly blackened.

remain in contact for two or three minutes, the paper was immersed in running water and was washed for an hour or two.

On applying the oxalate developer nothing appeared. Feeling confident that effect must be produced, the experiment was repeated several times and the results were closely examined. On one specimen it was found that the characters had appeared, but reversed, that is, lighter than the ground which had darkened by the development being pushed. This at once gave a clue; it showed that traces of the acid adhered too strongly to be removed by washing and by locally checking the development, interfered with the reaction. Accordingly, next time after a very short washing, the paper was immersed in water to which a trace of ammonia had been added, and after ten or fifteen minutes' action the ammonia was thoroughly washed out. The result was striking: as soon as the developer was applied the characters which had been traced with acid came out strongly as brown marks on a white surface.

Cold sulphuric acid even undiluted is generally held to have no action on silver haloids, but it is well known that the hot strong acid decomposes them. The foregoing experiments leave no doubt that the cold dilute acid produces an initial effect invisible to the eye but revealed by greater tendency to give way under the action of a reducing agent. This action of the acid comes therefore exactly into line with that of light and heat. In all three cases an effect is produced inappreciable until a reducing agent is applied. But in all three cases the agent which produced this invisible effect is capable by continued action under favorable conditions of bringing about a visible change without the aid of a reducing agent.

Light.—The silver haloids in their sensitiveness to light, show an important relationship to that of allotropic silver. When for example silver chloride precipitated with an excess of hydrochloric acid is exposed to light, the darkened product contains apparently no metallic silver* (it is probable that the trace of silver given up to nitric acid may arise from the decomposition of a very small quantity of subchloride). However this may be the subchloride and not metallic silver is the essential product.

This has always seemed a very enigmatical result. Two combinations of silver and chlorine exist; the one very stable, capable of fusion without decomposition, the other so unstable that it can hardly exist isolated, and yet the stable compound is rapidly broken up by light, even by a weak diffuse light,

* In some (unpublished) experiments made some years ago to test this point, I found that silver chloride exposed for several days to strong sunlight under water, with frequent stirring up, and subsequent washing yielded only a trace of silver to strong cold nitric acid after a contact of an hour.

while the unstable compound resists many days' exposure to the strongest sunlight.

In examining the action of light upon allotropic silver (see Part I) an equally remarkable effect was described. Although all the other forms of energy applied readily and quickly convert allotropic to ordinary silver, light (at ordinary temperatures), fails to effect this change even by exposures lasting for several months. If we conceive that the atomic form of silver which exists in AgCl corresponds to the allotropic form, and that the more condensed form of subchloride corresponds to the "intermediate form," we shall obtain a reasonable explanation of the action of light.

The inability of light to carry the change which it produces in allotropic silver beyond the "intermediate form" exactly corresponds to its inability to carry the decomposition of silver chloride further than to subchloride or rather to photochloride. (It is understood that the silver chloride here spoken of is that which is formed by precipitation with excess of hydrochloric acid). This explanation appears to remove a real difficulty, and at the same time establishes a perfect parallelism between that action and the action of light on allotropic silver.

Although the foregoing study of the silver haloids was made for the purpose of fixing the relations which exist between them and allotropic silver, the results nevertheless have much interest in relation to the haloids themselves and place their nature in a somewhat new light. For it is shown that these haloids, though substances in some respects of very great stability have their equilibrium so balanced as to respond to the slightest influence, not merely of light, but of any form of energy, not receiving a momentary but a permanent impression which, though so slight as to be invisible, still greatly increases the tendency of the molecule to fall to pieces under the action of a reducing agent. Further, four of these forms of energy, light, heat, electricity and chemical action, when more strongly applied totally disrupt the molecule. One form of energy, mechanical force, though capable of producing the invisible effect makes an apparent exception in respect of this ability to disrupt. This matter is now under examination and it will probably be shown hereafter that the analogies are complete and without exception.

The same completeness holds with regard to the analogies which form a principal subject of this paper, namely, those existing between allotropic silver and the metal as it exists in the salts of silver. No other salts but those of silver show this wonderfully balanced equilibrium, sensitive to all forms of

energy. But allotropic silver also shows an almost exactly similar capacity to respond to the influence of energy in all its manifestations by undergoing changes of a like character.

The inferences to be drawn from the foregoing seem to be as follows. That silver may exist in three forms: 1st. Allotropic silver which is protean in its nature; may be soluble or insoluble in water, may be yellow, red, blue or green, or may have almost any color, but in all its insoluble varieties always exhibits plasticity, that is, if brushed in a pasty state upon a smooth surface its particles dry in optical contact and with brilliant metallic luster. It is chemically active. 2d. The intermediate form, which may be yellow or green, always shows metallic luster, but is never plastic and is almost as indifferent chemically as white silver. 3d. Ordinary silver. . . . Further, that allotropic silver can always be converted, either into the intermediate form, or directly into ordinary silver; that the intermediate form can always be converted into ordinary silver, but that these processes can never be reversed, so that to pass from ordinary silver to allotropic it must first be rendered atomic by combination, and then be brought back to the metallic form under conditions which check the atoms in uniting. That allotropic silver is affected by all forms of energy, and that this effect is always in one direction, namely, towards condensation. That the silver haloids are similarly affected by the same agencies. That a remarkable parallelism is noticeable between the two actions, especially if we take into account that in the haloids the influence of energy is to some extent restrained by the strong affinity which the halogens show for atomic silver. There is therefore reasonable ground to suppose that in the silver haloids silver may exist in the allotropic form.

Philadelphia, March, 1891.

Art. XXIX.—*The Phenomenon of Rifting in Granite;* by Ralph S. Tarr.

[Published by permission of the Director of the U. S. Geological Survey.]

In the granite at Cape Ann and elsewhere it is noticed that the rock splits most easily in certain fixed directions; and it is by taking advantage of these lines of weakness, that large regular blocks are easily split from their bed in the quarry. An expert quarryman knows full well just what may be expected of the granite and in making his calculation, the prime factor is the direction and strength of the "rift." In many places there are other lines of weakness along which the

granite easily splits; but these lines rarely exceed three and they are termed respectively "rift," "cut off" and "lift." The latter is generally more or less horizontal; the "rift" is the stronger and the "cut off" the weaker of the two nearly vertical lines of splitting.

During the summer of 1887, as an assistant to Professor N. S. Shaler,* I made a careful study of the jointing and other phenomena exhibited in the granite quarries at Cape Ann,† and in the course of these studies became interested in the phenomenon of "rifting." Later some slides were cut with the idea of determining if possible the nature and cause of this phenomenon.

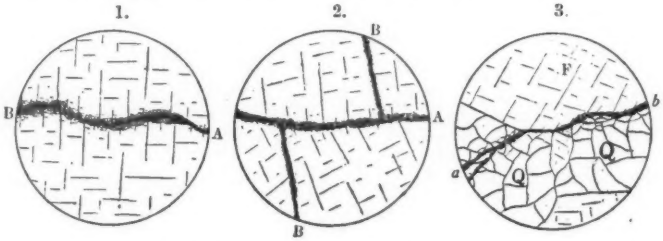
The Cape Ann quarries exhibit "rifting" in every form of variation. There are no two quarries in which the "rift" has the same peculiarities and in which it has exactly the same direction. In fact in the same quarry as in the case of the Rockport Granite Company quarry, the rift changes completely in different portions of the large pit. Furthermore, in one case, the "rift" becomes weak and the "cut-off" changes to "rift" in the same quarry. The reason for giving these facts is to show that there is such decided variation that the idea of attempting to explain the phenomena on the theory of widespread and uniform disturbance is out of the question, at least since the granite came into anywhere near its present position. That there has been much faulting in the granite is plain upon the most cursory examination. It might be reasonable therefore to suppose that the phenomenon of rifting was produced early in the history of the granite, and that the present variation is chiefly due to faulting and contortion.

The so-called granite of Cape Ann is a hornblendic granitite containing orthoclase and some plagioclase feldspar, quartz, hornblende, a very little biotite and some magnetite. Under the microscope it is found that the quartz and feldspar show signs of much strain. There are tiny irregular faults and fault breccias (figs. 1, 2 and 3) both in the quartz and feldspar. With the naked eye the rift can be plainly seen, when it is strongly developed, to be a slightly irregular break cutting the rock and crossing quartz and feldspar alike. With the petrographical microscope, the crack appears quite irregular, and it can be frequently traced around quartz grains rather than directly across them. The line of breaking will often turn to one side in order to take such an easy path, and when crossing the feldspar it generally, in fact as far as my observations extend, always follows cleavage lines. Macroscopically

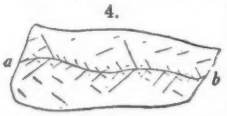
* While much of the detailed work was done by the writer, the general scheme and most of the conclusion must be credited to Prof. N. S. Shaler.

† See Ninth Annual Report U. S. Geol. Survey.

the line does not appear as a fault but simply a crack; but microscopically extremely minute faults can be detected, and the universally present fault breccia proves actual dislocation.



The fault breccia is in reality a breccia, not as I at one time suspected a secondary development, for in several places I found pieces of feldspar only partially removed from the main crystal in such a way as to show the continuation of cleavage lines from the main piece into the dislocated portion. Along the fault lines in the margin of the feldspar, cleavage lines are frequently developed, and these tend to hide the fact that dislocation has actually occurred (fig. 4).



Rifting is, then, dependent upon the thousands of minute dislocations which occur in every cubic inch of rock. The strains which produced these dislocations were of such a nature that three distinct sets were produced. I refer to Professor Shaler's article on Cape Ann in the Ninth Annual Report of the U. S. Geological Survey for 1887, for a full statement of the joint planes in the Cape Ann quarries. In this statement one of the most striking facts brought out, especially in the diagrams is that the joint planes follow distinct systems. There are three of these systems, one nearly horizontal and two vertical. The horizontal system is probably a contraction jointing formed during the cooling of the granite. These joints are irregular both in position and dip, are usually more or less dome-shaped, and lie one beneath another in concentric layers. The vertical sets of joints are much more regular, and are frequently perfectly straight cracks for several hundred feet horizontally and more than fifty feet vertically. They form with each other an angle several degrees less than a right angle. In almost any quarry these systems of jointing may be readily detected. Other joints occur, striking in almost every direction; but they are clearly accidental being most commonly diagonal across a block formed by the main joint planes, while the two main sets of vertical joints are the

result of one general cause, and in consequence follow a general law. In different portions of the Cape, the joints extend in different directions, but these variations may be readily explained on the supposition of faulting which has clearly been extremely common in this granite mass. In a number of cases the rift is found to follow the same general direction as the principal set of joints. This is particularly the case where the rift is well developed, as for instance in the quarries at Bay View.

In regard to the age of the rift, I can say very little that is definite. A careful study of 70 slides, cut from specimens of rock taken from the diabase dikes of Cape Ann, failed to show any sign of rift. From this it would appear that the rifting tendency was induced before the dikes were injected into the granite, but as the dikes mainly follow the joint planes, this is of little value in placing the age of the disturbance. There are some ragged dikes of quartz porphyry which were intruded before the jointing, but these show no signs of rifting. The evidence furnished by the dikes, however, is of little value for fine-grained rocks would not be likely to show evidence of microscopic faults. This fact is particularly well seen in the Cape Ann granite, in places where there are fine grained basic segregations. These segregations are as old as the granite, yet they show no rifting, although the surrounding granite has a very strong rift. The older dikes of quartz porphyries, and ragged diorite are very much faulted macroscopically, and very much changed in mineralogical composition microscopically, showing that there has been much motion and consequent alteration.

I suspect, although no evidence that I have been able to find conclusively proves it, that rifting and jointing are closely associated phenomena, and that the cause which produced one caused the other. What this cause was I shall not attempt to say, though plainly it was one of great extent and vast force. Between the almost microscopic rift and the joint plane hundreds of feet in linear extension, I have been unable to find any satisfactory gradation. Even the similarity in direction is not as striking as could be desired, to prove the connection. At Bay View, however, where the rift is remarkably strong, in some exposed places it has doveloped into many small parallel joints. These joints are about six inches apart; but if the rock is struck with a hammer it cleaves into many pieces parallel to these rift joints. Certain so-called "green seams" have been observed to pass out into rift-like breaks. These "green seams" are imperfect joints, lined with a thin layer of chloritic matter, which are not generally noticed by the quarrymen; but along which the rock is liable to split if

it is allowed to fall or is otherwise jarred. In one of these breaks I could plainly trace the passage from a distinct "green seam" to a rift-like break and then into unbroken granite.

From these facts I have been led to the supposition that before the injection of the dikes, the granite was subjected to contortion and pressure, which finally resulted in the production of rifting. Contortion would, it seems to me, produce just such a weakness in a hard, brittle, quartz-bearing rock. If, now, along some line of weakness in this partially rifted rock, the cohesion is overcome by the strength of the force which is compressing the mass, a joint plane would be formed. The probabilities are that the joint would be nearly parallel to the general rifted weakness, or else along the other line of weakness approximately at right angles to this. The third or horizontal set of "rift" planes, the so-called "lift" may have been a weakness inherent in the granite on account of the contraction of the mass during cooling. Subsequent faulting has displaced the granite, and broken it into such a number of pieces that we can no longer trace the general cause of rifting any better than we can that of jointing.

There is another possible explanation of rifting. There are in Cape Ann several hundred dikes, in many cases extending no doubt completely across the island (see Ninth Annual Rep. U. S. G. S., 1887—Shaler). The injection of this matter has expanded the bed rock several per cent more than its original bulk. This expansion must have been accompanied by a condition of great strain, perhaps enough to account for the breaking of the granite into its present rifted form. As the dikes for the most part follow the prevalent joint planes, these must have existed before the dikes were injected. This fact that the dikes follow the joints would explain the apparent similarity in direction of the joint and rift planes; and the absence of rift planes in certain places could be explained, either by the absence of dikes in that vicinity, or by some local peculiarity which relieved the pressure. The one fact which militates against this hypothesis is that there are no signs of rifting, and very little sign of strain in any of the earlier dikes which follow the joint planes, although they must have been subjected to great pressure during the injection of the later dikes. Altogether it seems to me more reasonable to suppose that the joints and rift phenomena are due to the same general cause, especially since there is a certain parallelism in direction between the two.

The inquiry then stands in rather an unsettled condition. The phenomenon of rifting is dependent upon certain microscopic breaks and even faults. There is a certain though not very definite parallelism between joints and rift and in some

cases the rift has actually developed into a joint. These facts indicate, though rather indefinitely, a common origin for the two phenomena though it is not impossible that the rifting phenomenon is subsequent in origin to the time of formation of the joint planes and possibly the result of the intrusion of the great number of dikes which cut the granite base of Cape Ann, and which must have brought about a condition of intense strain in the mass. A careful study both in the field and the laboratory fails to bring about a definite and satisfactory explanation of the cause of the phenomenon; and its settlement must await studies in other regions where dikes are less abundant.

Aside from the economic value of the rifting tendency there is a geologic effect of considerable importance dependent upon it. It was noticed in the study of the Cape Ann region that certain of the bowlders in the morainic drift had a tendency to crumble while others had no such tendency. This crumbling has gone so far that glacial bowlders which at the time of their transportation must have been solid and in a measure fresh, have, since the end of the glacial period, completely decayed to a crumbling mass of gravel. All stages in this decay may be seen on the island of Cape Ann. At first it was thought that this was the result of some chemical weakness in the rock, but a microscopic examination proved that the weakness was not chemical but mechanical. Whenever the rift is strongly developed the rock has the tendency to decay along the rift breaks; and at places, notably at the Bay View Quarry along the line of the railway in a fresh cut not more than fifteen years old, the decay along the line of the rift has not only developed well marked joint-planes but has begun to crumble the granite into gravel. A better case than this even is illustrated in the photograph (Plate LI, 9th Annual U. S. G. S.), where several large bowlders of degradation have resulted through the agency of the weather acting along the rift planes in post glacial times. Thus the phenomenon of rifting is, in the Cape Ann region at least, an important geological agent because of the aid which the lines of mechanical weakness furnish the agents of disintegration. Prior to our investigations, so far as I know, no notice has ever been taken of the phenomenon of the rift, yet I have no doubt it will be found to be of equal importance in many other localities than the one studied.

Art. XXX.—*The Redrock Sandstone of Marion County, Iowa;* by Charles R. Keyes.

[Read before the Iowa Academy of Sciences, September 5, 1890.]

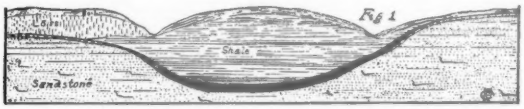
The sandstone of Redrock, in Marion County, Iowa, has recently come into prominence as a building stone; and is now used more or less extensively throughout the State for the better class of architectural work. Long ago this rock was utilized in various structures at DesMoines and elsewhere, but the method of obtaining it, by blasting, shattered the stone so as to render it almost worthless for building purposes. It soon fell into disrepute and for more than thirty years has not been used except for unimportant local masonry. Recently extensive steam sawing apparatus has been brought in and the stone removed in huge blocks before reduction by further sawing to sizes required. In this way the sandstone is not injured as when the blasting method was in vogue. The resistance to crushing power of the better portions of the rock is now considered to be nearly equal to any in the country.

The Redrock sandstone has long attracted popular attention. The bright vermillion cliffs rise to a height of one hundred to one hundred and fifty feet above the water surface of the DesMoines river. The red coloration of the rock is, however, local, merging laterally and downward into a yellow or buff color. The formation has a known geographic extent of at least twenty miles and probably stretches out much farther. At Redrock cliff the stone is, for the most part, massive; but rather soft and thin-bedded above. At this place it is a very fine grained and homogeneous sandrock, some portions even affording excellent material for grindstones. But southwestward, and at Elk bluff two miles below, the sandstone passes into a fine-grained, ferruginous conglomerate. The dip is everywhere to the south and west; and, at a short distance above the quarry just alluded to, the inclination is very considerable. A mile beyond, the sandstone has disappeared completely and the section shows only shales and clays. The space between the latter exposure and the last known outcrop of the sandstone is perhaps half a mile, the interval being hidden by Quaternary deposits down to the water-level. The abrupt change in the lithological characters of the rocks in so short a distance has been mentioned by Owen* and Worthen,† but the true explanation is entirely different from the suppositions of those writers.

At Redrock quarry the strata overlying the sandstone are disclosed as shown in figure 1, the horizontal and vertical scales

*Geology Minn., Iowa and Wisc., 1854. † Geol. Iowa, 1858.

being the same. The full thickness of the sandstone is not represented in the cut. The upper limit is very uneven and



paved everywhere with rounded water-worn bowlders and pebbles, derived from the sandstone itself. A gray fire-clay covers this pavement and upon it rests a coal bed having a thickness of six feet centrally, but rapidly thinning out laterally in both directions to a very unimportant, scarcely recognizable, bituminous seam. Northward, or at right angles to the face of the section, the coal is thicker. Superimposed upon the coal are drab and ash-colored, clayey shales, having an exposed thickness of thirty feet, but which are manifestly much more extensive. From a consideration of this section, then, it is clear that before the superimposing coal seam was formed the vast sand bed had been raised above the surface of the waters, consolidated, and was then subjected to considerable denudation. In a small gorge or ravine, excavated in the sandstone, the carbonaceous material was deposited as the land was again being submerged. Immediately to the north of the section represented in the figure (which faces the south) the corrasion was much more extensive, as is shown by the rapid inclination of the axis of the gorge in that direction; so that the section is actually across a tributary ravine opening into a large basin in which the coal is now mined in large quantities. The inference is, then, that the abrupt disappearance of the vast bed of sandstone in such a short distance as half a mile above the quarry, where it has an exposure of more than one hundred feet, is not due wholly to the inclination of the stratum, but is the result of great erosion in that direction, previous to the deposition of the shales and clays; and that the massive sandstone really formed a bare hill of considerable height against which the subsequent deposits were laid, when the conditions for such a change occurred.

Three miles down the river from the Redrock quarry is another instructive exposure. A small but deep ravine divides the section. On the left is the concretionary limestone—the last outcrop of the St. Louis in Central Iowa to be noted in the ascent of the DesMoines river. At this place it rises in a low arch about fifteen feet above low-water. Overlying it are marly and somewhat sandy clays or shales which have a vertical exposure of sixteen feet. The strata dip 10° to the

eastward. On the right a fine-grained ferruginous conglomerate—an extension of the Redrock sandstone—rises in vertical cliffs to a height of one hundred and fifty feet. The inclination is 5° to the westward; but the dip is perhaps even greater to the southwest. The strata are visible down to the water's edge. The direct line of contact between the arenaceous and calcareous beds is not shown, as the detritus brought down by the streamlet and the alluvial material deposited at its mouth by the DesMoines during high water completely conceals the stratified rocks for several yards on each side of the entrance. In his ascent of the DesMoines river in 1852, Owen observed the same exposure and thought that it indicated a fault of one hundred and fifty feet or more. It is more probable, however, that the case is one similar to that exhibited at the Redrock quarry; and that the limestone area at the time of deposition of the sandy material was a slowly sinking island or low promontory, which was eventually completely covered by the arenaceous deposit.

At all appearances here was an extensive sandstone formation, with a maximum thickness of more than one hundred and fifty feet, lying unconformably upon the St. Louis limestone and with coal-bearing strata imposed unconformably upon it. At first it was thought that the sandy member represented shore or estuary deposits of the Kaskaskia sea. Such, however, was found not to be the case. A few miles below, exposures were observed showing fully seventy-five feet of dark sandy, clayey and bituminous shales between the sandstone and the concretionary limestone. The shales carry at least two workable seams of good coal, one of which attains a thickness of five to seven feet and has a very considerable geographical extent.

As exposed along the DesMoines and Skunk rivers the upper portion of the St. Louis strata is made up of blue and gray fragmentary limestone, overlain usually by several feet of gray, highly fossiliferous, marly clay. The most characteristic and widely distributed fossils are: *Spirifera Keokuk* Hall, *Pentremites koninckiana* Hall, *Athyris subquadrata* Hall, *Zaphrentis spinulifera* Hall and *Productus marginicintus* Prout. There are also a number of monticuloporids, terebratulæ, lamellibranchs, and a few gasteropod and trilobite remains. In many places the St. Louis formation exhibits considerable surface erosion due to subaerial agencies that acted before the deposition of the lower Coal-measures; and the soft marly upper member has been largely removed. The superimposing strata thus rest sometimes on limestone, sometimes on marl.

The detailed stratigraphy of the dark, coal-bearing shales immediately beneath the Redrock sandstone is exposed a short distance below the village of Redrock. The coal seam is from four to five feet in thickness; and is overlain in places by a few feet of alternating sandy and clayey shales. In the sandstone directly over the coal are vast numbers of finely preserved vegetable remains: huge lepidodendrids and sigillarids of eight, ten or more species, massive calamites and delicate ferns, abundant but not packed together in confused masses.

The recent observations have cleared up many of the hitherto doubtful points concerning the geological history of the Redrock sandstone. It is not the basal member of the Coal-measures, as was regarded by Worthen; nor is it a shore extension of the Kaskaskia limestone; neither is its geographic extent as limited as had been supposed. Twenty miles to the southeast of Redrock a sandstone of great thickness, having identical lithologic characters and with a similar stratigraphical position is believed to be its extension southward. And it may also rise a few feet above low-water in the northwestern corner of Marion county. The most interesting consideration in regard to this Redrock sandstone is the fact of its considerable elevation above the surface of the sea and its subjection to subaerial erosive agencies for a long period of time before submergence again took place. During that interval the great thickness of sandstone probably was almost entirely removed in places.

The southern prolongation of the formation yet remains to be made out and its geographic limits eastward and westward from Redrock village more definitely determined, for there is every reason to believe that it extends beyond the boundaries at present known.

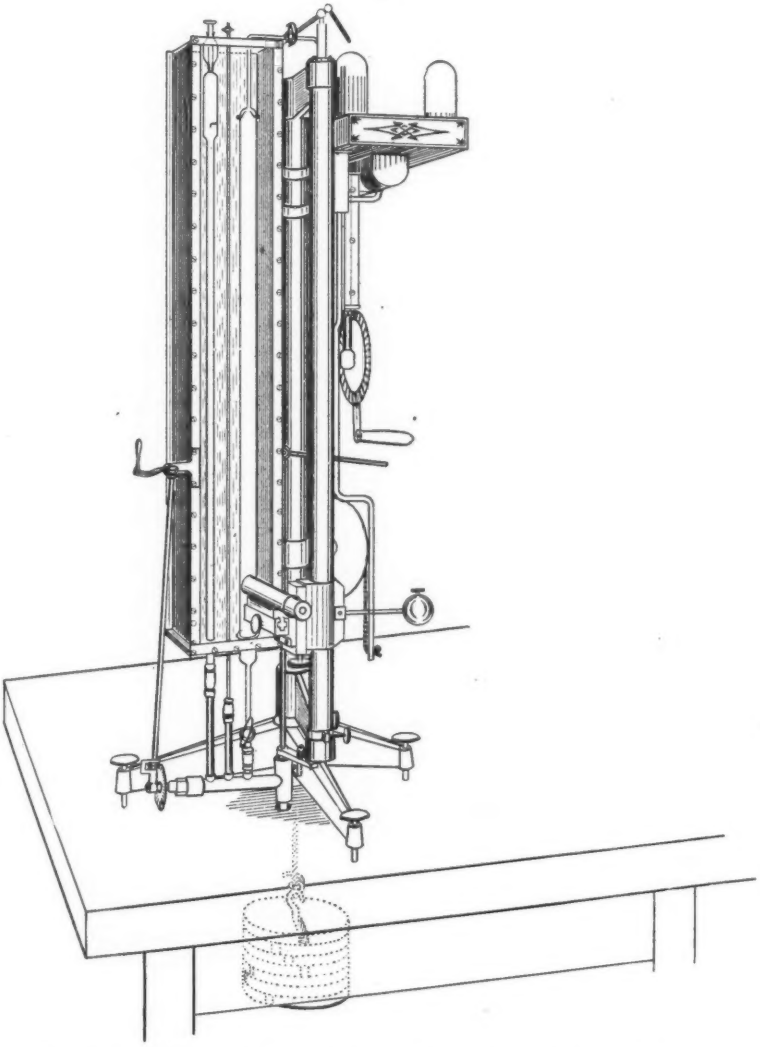
Art. XXXI.—*The Volumetric Composition of Water;* by Edward W. Morley.

[Continued from page 231.]

Apparatus for accurate measurement of volumes of Gases.—My measuring apparatus has finally become rather elaborate. It is shown in fig. 3. It is mounted on a stone pier, independent of the floor of the room in which it stands. The eudiometer and measuring tube ends above in a stopcock and recurved tube whose end is seen to emerge inside the left hand gas jar in the cistern. The stopcock is manipulated by means of a metal shaft and long handle, seen at the top of the column which carries the reading microscope. At the bottom

of the eudiometer is a glass stopcock of large bore intended to facilitate the washing out of the eudiometer after an analysis.

3.



For this purpose the glass plug of the stopcock is withdrawn and a duplicate plug inserted in which there are such connec-

tions that the part below the stopcock is shut off, and an opening is left between the eudiometer and the outside of the apparatus. By connecting the top of the eudiometer to an air pump, aqua regia or potassium hydroxide can be drawn into the eudiometer; then by connecting the bottom of the eudiometer to the pump, distilled water can be drawn in at the top. In this way the tube was kept so clean that carbon dioxide was formed only twice, when this washing was omitted; accurate reading of volumes were also facilitated. Below the glass stopcock, the eudiometer is connected by a rubber connector, to a steel tube screwed into an iron stopcock. The key of this stopcock is prolonged upwards some four decimeters, and ends in the handle seen just above the reading microscope. A small wheel imperfectly seen under the reading microscope carries a series of stops of which any one can be brought into position so as to arrest the opening of the stopcock at a determinate point. This stopcock governs the admission of mercury from the movable reservoir carried vertically by an apparatus placed on a table to the left. The iron stopcock has three steel tubes which are connected, one to the eudiometer as said before, the others to the two pressure tubes; the smaller of these is an auxiliary, used for all rough measurement, so as to reserve the other for the final accurate measurement. This tube is shut off from connection with the other tubes by a piston valve whose motion is produced by the geared wheels seen at the left of the iron stopcock. Its vacuum was easily kept unimpaired for months, as was proved by repeated determinations. But further, this piston valve also served as a micrometric adjustment of the level of the mercury in the eudiometer and pressure tubes. The use made of this will be mentioned below, and it contributed greatly to the accuracy obtained. These three tubes were enclosed in a box with glass front and back, and filled with clear water kept stirred by a current of air. The eudiometer is secured into a brass plate which is ground water-tight to the bottom of the box: on removing a clamp, the eudiometer can be lifted out of place if necessary, and can be replaced without a variation of its level amounting to the hundredth of a millimeter. It was convenient to compute the measured volumes of gases by means of an interpolation formula whose constants depended on the relative levels of fiducial marks on the eudiometer and pressure tubes, and constancy of this relation even after removing the eudiometer, was highly desirable. The pressure tube was provided with a fine screw motion by which it could be adjusted vertically while in position and filled ready for use.

The recurved tube at the upper end of the eudiometer serves for the introduction of gas into the apparatus. The

cistern containing the jars of gas is capable of the motion required to bring the open end of this recurved tube inside of the jar *ab* and to its top. When the cistern is in its highest position, the recurved tube is wholly contained within the well seen under the cistern, and the cistern can be moved vertically by a distance equal to the height of the tallest jars used. It is fitted with sliding ways, counter-poised, and moved by a screw; by means of a multiplying gear, its motion can be made as rapid as is convenient; by means of the adjustable counterpoise, the cistern with its thirty-five kilograms of mercury can be moved up and down and placed accurately at the required level with ease and safety. In the center of the cistern is a well for filling the jars used: the rest of the bottom is inlaid with a smooth surface of slate. Care was taken to have no crevices in which air could be entangled, from which perhaps it should rise into a jar of gas. The mercury was always kept as much as three centimeters deep, to lessen the probability that gas in the jars should be contaminated by diffusion between the walls of the jar and the mercury in contact with them. But the danger of this contamination is very slight. I left two jars of hydrogen standing in the cistern for eleven weeks, after which time I was unable to detect any contamination. The reason of this, so different from the result obtained by Faraday,* is probably the great care taken in filling the jars with mercury. The jar was always put entirely under the surface of the mercury while it was closed with a glass plate, so that no dust from the free surface of the mercury could get to the inside of the jar.

The vacuum in the pressure tube was obtained by exhausting the tube from above while the bottom was closed, then admitting mercury till it rose above the glass stopper at the top of the tube; during the exhaustion, the stopper was loosely in place, and was in the vacuum. When the stopper was covered by mercury, it was forced into place; a drop of water had previously been put in the upper part of the pressure tube. In the pressure tube were two Jolly points; of which sometimes one was used, sometimes the other, an interpolation formula having been computed for each of the two systems of pressures measured by the mercury when brought to one of the points. The vacuum in the pressure tube was often measured or rather, the real zero of pressures was determined by producing a good vacuum in the eudiometer, bringing the mercury in the pressure to one of the Jolly points, and observing the level of the mercury in the eudiometer; this level was the zero from which pressures were counted, and could be

* Annals of Philosophy. [II], vol. xii, p. 389, 1826; Poggendorff's Annalen der Physik, vol. viii, p. 124, 1826.

verified as often as desired, and did not change during the series of experiments.

The measurement of the reduced volume of a gas is effected by adjusting the apparent volume till the mercury in the pressure tube stands at one of the Jolly points, and measuring the level of the mercury in the eudiometer. This reading determines the apparent volume, and the difference between this reading and the reading of the zero point gives the pressure under which the gas is measured. A convenient interpolation formula reduces the computation to the addition of a constant to the reading, taking the doubled logarithm of the sum, and adding a logarithmic constant.

The measurement of the level of the mercury in the eudiometer is made by means of a reading microscope. This is carried on a cylinder supported on the frame work of the instrument, and provided with a tangent motion. On this cylinder slides a piece which can be tightly clamped, and which carries ways on which the microscope can be moved vertically by a micrometer screw. When the microscope is made to give distinct vision of a scale engraved on the eudiometer, the terminal lines of an eye-piece micrometer are made to agree with two successive millimeter divisions of the scale. As these are but the three hundredth of a millimeter wide, the coincidence can be made accurately. When coincidence is secured, the microscope is made to give distinct vision of the meniscus and the illumination arranged. When the mercury is now made to coincide accurately with one of the Jolly points in the pressure tube, the reading of the fraction of a millimeter by which the mercury in the eudiometer stands above a millimeter division of the scale is accomplished in a few seconds. Great care was taken in the calibration of the eudiometer. For this I fused to the end of the recurved tube, mentioned before, a further tube opening downwards Through this air-free water was introduced into the eudiometer. The mercury reservoir being raised, mercury was admitted by opening the iron stopcock against the proper stop. Water then began to drop from the added tube. The rate of admission of mercury must be so slow that the amount of water left adhering to the inside of the eudiometer is small, and is nearly constant from one experiment to the next. Three hours for the admission of eighty centimeters of mercury gave concordant results. When the mercury reached the lowest point to be calibrated, the iron stopcock was closed, and the level of the mercury and the temperature of the water determined. The tube from which the water had been dropping was wiped in a constant manner, and a tube put in place to collect the water which now issued on opening the iron

stopcock. When the mercury rose to the next standard point, level and temperature were measured, and another tube placed to collect water, while the water already issued was weighed. True volumes at zero were computed from the weights and temperatures observed. The calibration was made four times; I give the values found for the points at which oxygen and hydrogen were measured in the experiments, and the differences between the mean and the several determinations. It will be seen that the mean error of a single determination of volume is five cubic millimeters. A tube was previously cali-

Scale Division.	Volume found.	Errors (cubic millimeters).			
		1.	2.	3.	4.
600	184·323	0	12	− 7	− 4
625	191·849	−3	− 4	4	4
650	199·442	1	− 2	10	−10
675	207·082	7	−15	2	7
700	214·766	−1	3	5	− 7
725	222·460	1	4	−10	5
750	230·132	−1	− 3	− 1	5

brated with a mean error only three fifths as much; but it broke during the first experiment. The sky was so cloudy while this the present tube was calibrated that illumination was defective, and work very trying. But in the determination of the volumetric composition of water, any slight errors, either in the calibration of the standard points, or in the interpolation at intermediate points, was nearly eliminated by a proper distribution of the points used in the measurements.

Since, in my way of manipulating, the gas, scale, mercury, and eudiometer are all at the same temperature, the effects of the expansions of all were taken into account in one factor, which moreover, was determined for the actual degrees of the thermometer used.

In measuring the volume of a quantity of gas in the eudiometer, the mercury in the recurved capillary tube was brought to a certain mark. The level of the mercury in the eudiometer was so adjusted that when the pressure tube was opened, the mercury in it would stand near one of the Jolly points. Then the level of the reading microscope was adjusted, and the meniscus was brought into focus. During this time, the water surrounding the eudiometer was stirred by a current of air. When everything was ready, the current of air was shut off, and the piston valve slowly moved till the mercury exactly coincided with the Jolly point. Then, within five or ten seconds, the thermometer was read and the fraction of a

millimeter shown in the reading microscope was determined. The water was then again stirred, the adjustment at the Jolly point, and the reading of the thermometer and of the reading microscope was repeated. By means of the fine adjustment of the level of the mercury which has been mentioned, the adjustment at the Jolly point could be made within the five hundredth of a millimeter, and it could be repeated as many times as was desired. It was also possible to make the final adjustments, and the two readings, within a time too short for any change of temperature in the gas to be measured. Readings of temperature were to the two hundredth of a degree, and of level to the two hundredth of a millimeter. To show what degree of accuracy can be obtained by an apparatus such as is here described, including both errors of readings and errors of transfer due to bubbles of gas entangled in the capillary tube, I put a quantity of gas in a jar in the cistern, transferred it to the eudiometer and measured it, transferred it back to the jar and measured it again, and so ten times. I give the reduced volumes so found. From this it seems that the probable error of measurement, not including errors of calibration, are something like a seventy-thousandth part of volumes like those used in the determinations of the volumetric composition of water. I also found the mean error of a single measurement by computation from the mean error of a determination of the ratio sought. In this way, it seems that the mean error of a single measurement of such a volume as one hundred and fifty or two hundred cubic centimeters is its fifty thousandth part. This value *includes* the errors of calibration as far as they affect a determination of the ratio. The direct determination of mean error of measurement was made under selected conditions as to illumination and health which could not be secured in the determinations of the ratio.

Repeated measurements of the same volume of gas, transferred to jar after each measurement.

210·81^{cc}	210·805^{cc}
210·815	210·815
210·815	210·81
210·815	210·81
210·815	210·81

Determination of nitrogen contained in the hydrogen used for determination of the volumetric composition of water.—The parts p, q, r, were exhausted, filled with hydrogen, from n, and again exhausted. The pressure of the gas in n, was then measured by means of m, and its temperature by thermometers at n. From this, with the known volume of n, and

its connections, could be computed the reduced volume of the gas in n; then r was heated, and the valve o was opened. When about a liter of hydrogen had been taken from n, o was shut, and the volume remaining was determined. The heating of r was continued till the gas remaining was reduced to some such volume as ten cubic centimeters, when r was cooled, and the gas was extracted by the Sprengel pump. A suitable excess of oxygen was extracted from its store, the two gases were measured, mixed, exploded, and the residue measured. From this was computed the amount of hydrogen found by analysis, whence was learned by difference the amount of nitrogen which was originally contained in the volume known to have been extracted from n.

To illustrate by an actual experiment: In n, before extracting any hydrogen, the temperature and pressure were 766·5 millimetres, 20·5 degrees; after, 662·0 millimetres and 20·9 degrees. Hence it was computed that 823 cubic centimeters had been admitted to r. When r was cold, the hydrogen remaining was extracted, and transferred to the apparatus shown in fig. 3, and found to be 6·722 cubic centimeters at standard temperature and pressure. Oxygen was added, and the sum found to be 17·101 cubic centimeters. After explosion there remained 7·019 cubic centimeters. Hence the hydrogen found in the 6·722 cubic centimeters taken for analysis was 6·721 cubic centimeters. A duplicate analysis agreed well with this; so that this hydrogen was practically free from nitrogen.

Determination of the volumetric composition of water.— Two jars of hydrogen were extracted from n without heating r, and a jar of oxygen from the store of oxygen. I measured a convenient volume of hydrogen; for ease of explanation, suppose it was 180 cubic centimeters. About 120 cubic centimeters were transferred after measurement to a jar in the cistern, and the other 60 to a second jar. Then a volume of oxygen either a little smaller or a little larger was measured; suppose it was 175 cubic centimenters. After measurement, it was transferred to three jars, 60 cubic centimeters to the jar having 120 of hydrogen, 60 to the other jar of hydrogen, and 55 to a small graduated jar. Another volume of hydrogen was next measured, say 179 cubic centimeters. One-third of this was put into the jar into which the smaller quantity of hydrogen had been put before, and the remaining 120 cubic centimeters were left in the eudiometer.

It will be noticed that the three measurements are made at as nearly the same point as is consistent with the fact that there must be a slight excess of either one gas or the other. It would probably have been better to have made the three

volumes as nearly equal as possible, and then to have measured a small excess at the point at which the excess was to be measured after the explosion. But this was not thought of in time As it was, errors of calibration could have no great effect; but they were further made of still less effect on the final mean in two ways. In some experiments, the hydrogen was put in excess, and in some, oxygen; if in two such experiments the sum of the two gases were the same, the points of measurement of oxygen and of hydrogen would be interchanged, and the errors of calibration would produce contrary effects. Again, the amounts of gas taken were increased from time to time, so that all points from 63 to 75 centimeters were used, by which also accidental errors in calibration were rendered of small influence on the result.

The measured gases were now ready for explosions in fractions. Explosions were always made in the presence of a large volume of inert gas. The ratio of explosive gas to inert was varied within somewhat wide limits, and the same ratio was preserved throughout all the explosions of a given experiment. Suppose that in a given case the ratio desired was that of four to one. To the 120 cubic centimeters of hydrogen left in the eudiometer were added 30 from one of the jars containing hydrogen and oxygen. After this was exploded, a like volume was added again, and so on, till all the gas previously mixed had been consumed. There would still be 120 cubic centimeters of hydrogen in the eudiometer. To this was now added eight cubic centimeters of oxygen from the small graduated jar. The two were mixed by letting mercury drop through the eudiometer, and were exploded. A smaller computed volume of oxygen was added and mixed for the next explosion, and so on, till all the oxygen was finally exploded in presence of fifteen times its volume of hydrogen. But when oxygen was to be finally in excess, a variation was made a little before the last explosion, by adding small quantities of hydrogen to an excess of oxygen in the eudiometer; up to this point, hydrogen was kept in excess. It is obvious that the last explosion of the series is the critical one on whose completeness accuracy depends; sufficient attention was given to this matter.

After the explosion was completed, it cost some trouble to put the eudiometer into condition for good measurement, because so much water had accumulated in it. Then an excess of oxygen or of hydrogen, as the case might be, was added, the mixture was exploded and the residue was measured. From this was computed the amount of nitrogen in both gases taken together; subtracting the nitrogen known to exist in the hydrogen according to the previous experiment the remainder was the nitrogen in the oxygen used. The ratio of the volumes

of hydrogen to oxygen in water could then be computed. As to the chemistry, consumption of oxygen by oxidation of mercury or of fat, and the possible production of hydrogen dioxide had to be considered.

When mercury is oxidixed in the eudiometer, it is by the oxidation of fine globules on the walls of the eudiometer. In mixing the last third of the oxygen with hydrogen, it was convenient to let a current of mercury run down through the eudiometer; which covered its walls with mercury. In three experiments, some of this mercury was oxidized; two experiments were lost. In the other, it was found possible to reduce the oxidized mercury by a managed explosion, so that the water produced was perfectly clear, as it was in all the other experiments.

There was no carbon in my gases before they were measured. In two experiments, when the eudiometer had not been cleaned, carbon dioxide was produced. This must have come from fat on the walls of the eudiometer forced down by the current of mercury which mixed the oxygen and hydrogen. Since the composition of the lubricant was well enough known, it was possible to add to the oxygen used in producing carbon dioxide, the amount used in the combustion of the hydrogen of the fat, and so deduce the value of the ratio sought. As to hydrogen dioxide, in the absence of sufficient knowledge of what might take place in an excess of oxygen, hydrogen was kept in excess till nearly the end of the series of explosions.

To illustrate by an actual experiment, I will give all details of experiment number 6. The first column gives the temperatures, the second the readings of the scale of the eudiometer, the third gives the reduced volume of gas deduced from each measurement, and the fourth gives the adopted mean, with the name of the gas measured.

Temperature.	Pressure.	Volume reduced.	Means.
19·87	688·75	174·333	
19·89	688·76	174·326	174·33 hydrogen.
20·26	680·62	169·954	
20·29	680·65	169·947	169·95 oxygen.
19·44	685·45	172·910	
19·47	685·47	172·905	
19·59	679·98	172·920	172·91 hydrogen.
20·18	137·92	7·797	
20·54	138·08	7·805	7·80 residue.
20·73	255·54	25·271	
21·78	256·02	25·269	25·27 residue and oxygen.
21·80	187·06	13·829	
21·76	187·05	13·830	13·83 residue 2.

1. $\frac{3}{8}(25{\cdot}27-13{\cdot}83)=7{\cdot}62^{cc}$, hydrogen in residue 1.
2. $7{\cdot}80^{c}-7{\cdot}62^{c}=0{\cdot}18^{cc}$, nitrogen in residue 1.
3. $0{\cdot}18^{cc}-{\cdot}00=0{\cdot}18^{cc}$, nitrogen in oxygen used.
4. $\dfrac{174{\cdot}33+172{\cdot}91-7{\cdot}62}{169{\cdot}95-0{\cdot}18}=2{\cdot}00047$; ratio sought.

The experiments made divide themselves into groups according to the purity of the gases used. In some, both gases contained nitrogen, in some, only the hydrogen, in some only the oxygen, and in some, both gases were pure; in some carbon dioxide was produced, although both gases were pure. I give in full the quantities measured or the quantities computed from them, in the case of the first experiment of each of these groups; but I selected the eighteenth experiment, rather than the seventeenth, so as to include one in which there was an excess of oxygen.

Number.	Pressure.	Temperature.	Hydrogen taken.	Oxygen taken.	Residue.	Hydrogen in residue.	Oxygen in residue.	Nitrogen in hydrogen.	Nitrogen in oxygen.	Carbon dioxide formed.	Oxygen consumed.	Amount to be subtracted from hydrogen	Amount to be subtracted from oxygen.	Hydrogen used.	Oxygen used.	Ratio.
	cm	°	cc	cc	cc	cc	cc	cc				cc	cc			
1	64	22	307·89	150·03	8·29	8·015	...	·11	·165	...	..	8·12	·165	299·77	149·865	2·00027
2	64	22	307·29	149·28	8·68	8·57	...	·11	·00	...	..	8·68	·00	298·61	149·28	2·00033
4	66	20	325·36	156·21	13·36	13·21	...	·00	·15	...	..	13·21	·15	312·15	156·06	2·00019
14	72	23	383·30	185·70	11·87	11·87	...	·00	·00	...	..	11·87	·00	371·43	185·70	2·00016
18	75	25	407·98	205·71	1·73	....	1·66	..	...	·065	·09	·00	1·75	407·98	203·96	2·00029

In the following table I give the approximate temperature and pressure at which the hydrogen and oxygen were measured in each experiment, the amounts of impurities found in each gas, and the amounts of hydrogen and oxygen consumed in the explosion, with the ratio thence deduced. The pairs of determinations which are bracketed together were made one immediately after the other of the pair, with the same stores of gas extracted at the same time, and as nearly as possible under the same conditions, except that different gases were in excess. This will explain why the amounts of impurities found in the oxygen used should show such agreement. The oxygen used in the experiments from the fourth to the twelfth was obviously undergoing slow admixture with air; which was suffered to continue, in order to see if the presence of nitrogen affected the ratio found. After a while, the crack in a glass tube which had shown itself was closed by fusion.

Number.	Temperature.	Pressure.	Nitrogen in hydrogen.	Nitrogen in oxygen.	Carbon dioxide produced.	Oxygen consumed.	Hydrogen consumed.	Oxygen consumed.	Ratio.	Gas in excess.
	°	cm	cc	cc						
1	22	64	·11	·165	----	----	299·77	149·865	2·00027	hydrogen.
2	22	64	·11	·00	----	----	298·61	149·28	2·00033	hydrogen.
3	19	66	·12	·00	----	----	316·45	158·205	2·00025	hydrogen.
4	20	66	·00	·15	----	----	312·15	156·06	2·00019	hydrogen.
5	20	66	·00	·15	----	----	325·36	162·67	2·00012	oxygen.
6	20	70	·00	·18	----	----	339·62	169·77	2·00047	hydrogen.
7	20	70	·00	·18	----	----	347·24	173·60	2·00024	oxygen.
8	20	72	·00	·31	----	----	364·58	182·28	2·00011	hydrogen.
9	20	72	·00	·31	----	----	386·65	193·31	2·00016	oxygen.
10	22	72	·00	·72	----	----	381·85	190·92	2·00005	hydrogen.
11	22	72	·00	·82	----	----	389·79	194·87	2·00026	oxygen.
12	22	73	·00	·82	----	----	395·75	197·85	2·00027	hydrogen.
13	23	71	·00	----	----	----	372·09	186·01	2·00038	hydrogen.
14	23	72	·00	·00	----	----	371·43	185·70	2·00016	hydrogen.
15	23	72	·00	·00	----	----	383·30	191·62	2·00031	oxygen.
16	26	73	·00	·00	----	----	383·51	191·74	2·00016	hydrogen.
17	26	73	·00	·00	----	----	392·58	196·27	2·00021	oxygen.
18	25	75	·00	·00	·065	·09	399·74	199·85	2·00020	hydrogen.
19	25	75	·00	·00	·065	·09	407·98	203·96	2·00029	oxygen.
20	24	75	·00	·00	----	----	399·21	199·59	2·00015	hydrogen.

Comparison of Results.

Experiment 1 is alone in showing impurity in both gases; its result gives 2·00027 for the value sought.

Experiments 2 and 3 showed nitrogen in the hydrogen; their mean is 2·00029.

Experiments from 4 to 12 showed nitrogen in the oxygen; their mean is 2·00021.

Experiments 13 to 17 and experiment 20 showed no measurable impurity in either gas; their mean is 2·00023.

In experiments 18 and 19, carbon dioxide was produced; their mean is 2·00025.

The mean of the seven experiments where oxygen is in excess, is 2·00023, and that of the thirteen in which hydrogen was in excess is also 2·00023. Weights were originally assigned to each result according to the circumstances of each experiment, but they did not change the final mean, and are not given. Four experiments were lost by accident, all others are given. The mean error of a single determination of the ratio is ·000075, or one part in 26000. The final mean value of the ratio is 2·0002.

Summary.

Pure hydrogen cannot be obtained from the purest commercial zinc. By the electrolysis of dilute sulphuric acid, with a proper purifying train, I have obtained hydrogen containing

less than the hundredth of a cubic centimeter of nitrogen in two liters of hydrogen, and containing no other impurity in amount large enough to be detected. By the use of a fusible metal valve, it was possible to obtain any required degree of exhaustion in the part of the apparatus designed to receive hydrogen from the generator. The hydrogen intended to be weighed was not suffered to take up mercurial vapor, nor that intended for analysis to be contaminated with organic matter. A supply of hydrogen sufficient for several experiments was so stored up as to be safe from admixture of air; so that by the apparatus described, the amount of nitrogen in it could be determined in duplicate, and other quantities identical in composition could be used for determining simultaneously the amount of nitrogen in the oxygen used, and also the volumetric composition of water. An apparatus for the measurement of gases has been constructed in which the mean error of measurement of the volume of hydrogen and oxygen used in the experiments has been less than one part in fifty thousand. With this, twenty experiments have been made (four others being lost by accident and not completed), which gave a maximum value for the composition of water 2·00047, a minimum value 2·00005, and a mean value 2·00023. Variations in the process gave no corresponding variation in the result. The mean error of a single determination was one part in twenty-six thousand.

For the present, then, we may believe that water, when the gases are measured under ordinary temperatures and pressures, is composed of 2·0002 volumes of hydrogen to one volume of oxygen; or that under ordinary conditions, the number of molecules in a given volume of oxygen is one nine thousandth part greater than the number of molecules in an equal volume of hydrogen.

Art. XXXII.—*On certain points in the Estimation of Barium as the Sulphate;* by F. W. Mar.

[Contributions from the Kent Chemical Laboratory of Yale College.—VI.]

In the received mode of precipitating barium as barium sulphate, three conditions are carefully observed—absence of excess of acid, slow mixing of the reagents and rest, before filtration, of twelve hours or until the precipitate has completely subsided. Usually, in this process, the precipitate is thrown out in a finely divided, milky condition and settles very slowly. My observation that the precipitate, under certain circumstances, is formed in a more crystalline condition

and settles rapidly led me to investigate the conditions of so rapid a precipitation. These quickly settling precipitates were noticed, in the first instance, in the action of sulphuric acid upon solutions containing a very large amount of potassium chloride with hydrochloric acid in excess. In the course of five or ten minutes the precipitate had completely settled and was found to be in a distinctly crystalline condition and much coarser than the usual form of precipitated barium sulphate.

At the time, it was thought that the cause of this rapid subsidence was the alkaline salt present, and, accordingly, a series of experiments was made in which potassium, sodium and ammonium hydroxides were added in varying amounts to about 400 cm^3 of water, hydrochloric acid added to more than acidity (but not in measured amount), 0·5 grm. of barium chloride introduced, and precipitation brought about by adding dilute sulphuric acid. Sometimes these precipitates settled rapidly, but as often came down in the familiar milky condition. Later, another series of experiments, in which the different conditions were more carefully regulated, was made thus: in 400 cm^3 of water were dissolved 0·5 grm. of barium chloride, 10 cm^3 of strong hydrochloric acid, and amounts of the alkaline chlorides varying from 5 grms. to 0·05 grm., the whole being precipitated with 10 cm^3 of a solution of sulphuric acid made by diluting the concentrated acid with three parts of water. These precipitates all settled rapidly, and the variation in the amounts of alkali seemed to exert no very marked influence. Finally, these experiments seeming to point to hydrochloric acid as the influential factor, a series of experiments was made to test the effect of varying the amount of this acid. From a solution containing in 400 cm^3 0·5 grm. of barium chloride and amounts of hydrochloric acid varying from 1 cm^3 to 50 cm^3, the barium was thrown out by means of 10 cm^3 of dilute sulphuric acid. This series showed that the hydrochloric acid had a very marked effect upon the precipitation of the barium sulphate. When only one or two cubic centimeters of hydrochloric acid were present, the precipitate appeared immediately, in a milky condition, and settled slowly; as the amount of acid was increased, a point was soon reached where the precipitate was not so quickly apparent, but settled out much more quickly and in a coarser condition. With 10 cm^3 to 15 cm^3 of strong hydrochloric acid in the solution, the precipitate settled clear in ten or twelve minutes and was in excellent condition for filtration. When the solution contained 50 cm^3 of the acid, the precipitate settled clear in five minutes. Upon adding the sulphuric acid to such very acid solutions, no precipitate shows for a moment, but then it separates in beautiful crystalline condition and falls almost immedi-

ately. It can be safely filtered with or without pressure in ten minutes. In one instance, in the course of the experiments just detailed, 2 grms. of barium chloride were precipitated in the presence of 30 cm^3 of hydrochloric acid, the precipitate was allowed to settle clear, and was then filtered and washed, the whole operation being completed in seven minutes. This rapid subsidence of the precipitate is seen in hot solutions only —75° C. being the lowest temperature compatible with the attainment of good results, and 85° to 90° better.

To ascertain whether small amounts of barium would be precipitated in like manner from these acid solutions, a series of experiments was made with solutions containing in 400 cm^3, 10 cm^3 of hydrochloric acid and 5, 10, 15, 20, 25, 30 and 50 milligrams of barium chloride, precipitation being brought about as in the experiments above. These solutions remained clear a few minutes and then a very transparent precipitate appeared, but in no case was it as pronounced as the more finely divided precipitate produced in a neutral solution containing 5 milligrams of barium chloride by the same amount of sulphuric acid. However, by giving a circular motion to the solution in the beaker, after about 20 minutes a small conical heap of barium sulphate was collected in each case in the center of the beaker.

Experiments were next undertaken to ascertain whether barium is completely thrown out of solution when precipitated under the conditions related above. The barium salt used in all the experiments described below, was obtained by finely powdering selected crystals of barium chloride and drying by pressure between blotting papers. Portions of the same sample were used throughout. The hydrochloric acid used was the chemically pure article of commerce and had a specific gravity of 1·20. The sulphuric acid used was obtained by diluting the pure concentrated acid with three parts of water and had a specific gravity of 1·28.

In the first series the barium salt was dissolved in about 400 cm^3 of water, 15 cm^3 of hydrochloric were added, and precipitation was brought about by adding 10 cm^3 of the dilute sulphuric acid. The precipitates were filtered, after standing about ten minutes, upon asbestos felts in perforated platinum crucibles.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.
(1)	0·5002 grm.	0·4760 grm.	0·0016 grm.—
(2)	0·5042 "	0·4812 "	0·0006 " —
(3)	0·5038 "	0·4786 "	0·0025 " —
(4)	0·5002 "	0·4760 "	0·0016 " —
(5)	0·5046 "	0·4812 "	0·0006 " —
(6)	0·5038 "	0·4804 "	0·0006 " —

The results of these determinations indicate plainly a loss of barium sulphate, but inasmuch as the felts used had been made very thin and it had been subsequently observed that a small quantity of the sulphate could be collected in one of the filtrates of the series by giving a circular motion to the water, it was thought that the thinness of the felts might offer an explanation of the loss and of the varying results of the series. The following series was, therefore, made in exactly the same manner except that care was taken to have the felts carefully made and reasonably thick.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.
(7)	0·5014 grm.	0·4785 grm.	0·0004 grm.—
(8)	0·2227 "	0·2122 "	0·0005 " —
(9)	0·5003 "	0·4773 "	0·0004 " —
(10)	0·5046 "	0·4814 "	0·0004 " —

These results are uniform and indicate a trifling loss only; though in the filtrates of these experiments, also, a very slight, but, as it proved upon refiltering, unweighable amount of the sulphate could be collected. The precipitate in the last of these experiments was filtered off almost immediately after precipitation, and before it had completely subsided. In another case the whole operation, including the three weighings necessary was conducted to a finish in forty-five minutes.

In spite of the appearance of the trifling deposit in the filtrate, the deficiency in barium sulphate in these determinations was not greater than should be expected from the accepted solubility of that salt in water. To ascertain the effect of strongly acid solutions upon the solubility of barium sulphate the following determinations were made.

In experiment (11) the same amounts of the sulphuric and hydrochloric acids, 10 cm^3 and 15 cm^3 respectively, were used as before, but the total volume was reduced to 100 cm^3. In (12) and (13) the same total volume as before, 400 cm^3, was used, but this volume contained 150 cm^3 of the strong hydrochloric acid instead of 15 cm^3 as in the preceding experiments.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.
(11)	0·5016 grm.	0·4888 grm.	0·0002 grm.—
(12)	0·5004 "	0·4779 "	0·0000 "
(13)	0·5001 "	0·4776 "	0·0000 "

It appears from these experiments that, as in the preceding series, the solubility of barium sulphate in solutions constituted as described is not increased by the free hydrochloric acid, and that the effect upon the solubility when this acid is present in

great strength is to make the precipitate rather more insoluble, if anything, than it is in water. In this connection, it should be remarked that experiments of Fresenius,* together with somewhat similar experience gained by the writer in another line of work not included in this account, point to the fact that the presence of an excess of sulphuric acid is an important condition of this high degree of insolubility. The exact amount of such excess has not been determined, but the amount used in the foregoing experiments seems to be sufficient.

In the preceding experiments, barium chloride was used in considerable quantity. The following determinations were made to ascertain whether very much smaller quantities of barium would come down as completely and as soon, or whether it is necessary to let the precipitations stand longer before filtration. In these experiments the barium salt was measured from a standard solution, containing 200 milligrams of the chloride to the liter. The amounts of hydrochloric and sulphuric acids, 15 cm^3 and 10 cm^3 respectively, and the whole volume of the solution was the same as in the former experiments.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Time in minutes between precipitation and filtration.	Error.
(14)	0·0030 grm.	0·0024 grm.	120	0·0004 grm. —
(15)	0·0050 "	0·0046 "	150	0·0002 " —
(16)	0·0050 "	0·0023 "	5	0·0025 " —
		0·0043 "	60	0·0005 " —
(17)	0·0050 "	0·0031 "	5	0·0016 " —
(18)	0·0050 "	0·0040 "	10	0·0007 " —
(19)	0·0100 "	0·0078 "	10	0·0017 " —
(20)	0·0100 "	0·0085 "	15	0·0010 " —
(21)	0·0100 "	0·0083 "	30	0·0012 " —
(22)	0·0100 "	0·0087 "	60	0·0007 " —

From these results it would appear that the precipitation, in the presence of hydrochloric acid to the amount indicated, does not take place so rapidly when the amount of the barium salt is small, but that two or three hours are sufficient for reasonably complete separation of the precipitate in any case.

In all the experiments described above there was no attempt at a gradual admixture of the reagents but they were measured out and at once added to the solutions, the whole being well stirred. From the results obtained, it appears to be established, as regards the usual precautions in precipitating barium by means of sulphuric acid, that, contrary to former usage, it is

* Zeitschrift für Anal. Chem., vol. ix, p. 62.

highly advantageous to have the solution strongly acid with hydrochloric acid; that it is not necessary to add the reagents drop by drop, but that the whole quantity required to complete the reaction may be added at once; that ordinary quantities of barium salts, in presence of a considerable excess of sulphuric and hydrochloric acids, are precipitated completely and at once, but that when only a few milligrams are present, the precipitate requires more time to separate under the same conditions. Two or three hours are, however, sufficient, and in no case is the excessive time of twelve hours required.

In the light of the fact demonstrated in the preceding account, that hydrochloric acid may be introduced freely, and without detriment to the quantitative exactness of the precipitation of barium in the form of sulphate from pure solutions, it seemed desirable to look somewhat into the question as to what the influence of a large excess of hydrochloric acid might be upon the well known contaminating effect of alkaline salts present during precipitation, especially as it is customary to attempt the purification of barium sulphate thrown down in the reverse of this process—the determination of sulphuric acid by means of a soluble barium salt—by digestion of the washed precipitate in hydrochloric acid. The following series of experiments was undertaken with this end in view. The details are shown in the tabular statement, precipitation being effected in the presence of free acid and the alkaline salt.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.	HCl in solution.	Alkaline Salts present.	
(23)	0·5092 grm.	0·5032 grm.	0·0169 grm.	+ 110 cm³	$KClO_3$	3 grm.
(24)	0·5027 "	0·4907 "	0·0107 "	+ 10 "	"	"
(25)	0·5026 "	0·4944 "	0·0154 "	+ 100 "	KCl	5 grm.
(26)	0·5045 "	0·4939 "	0·0122 "	+ 10 "	"	"
(27)	0·5020 "	0·4931 "	0·0137 "	+ 10 "	"	"
(28)	0·5013 "	0·4849 "	0·0061 "	+ 10 "	NaCl	"

From the results it is plain that, whatever may be the effect of digesting the washed precipitate in hydrochloric acid, the presence of this acid in large excess during precipitation in the presence of alkaline salts, does not prevent contamination of the precipitate. On the contrary, the greatest contamination seems to have occurred in those cases in which the acid was present to the largest degree, but, in view of the slight variation in contamination as compared with the great differences in the amount of acid employed, it does not appear probable that the increase of acid has very much to do with the amount of contamination.

It likewise seemed to be a matter of some interest in this connection, to investigate the process by which it is currently

supposed* that barium sulphate carrying alkaline salts may be effectually purified, viz: by the solution of the washed precipitate in strong sulphuric acid and reprecipitation by water. Accordingly the determinations of the following series were undertaken. The barium sulphate, precipitated from solutions containing 5 grms of potassium chloride and 10 cm^3 of hydrochloric acid, was collected upon a filter, either paper or asbestos, and, after burning the paper or removing the precipitate from the asbestos (by tapping the crucible which held it and brushing out with a camel's hair brush), was dissolved by warming with concentrated sulphuric acid in a large porcelain crucible and, after cooling, poured into water containing 15 cm^3 to 20 cm^3 of hydrochloric acid. The water into which the solutions in strong acid was poured was warmed with a view to diminish the milkiness of the precipitate, but care must be taken to keep the temperature below 60° C. to avoid danger of spattering on the addition of the sulphuric acid. In the last two of the experiments recorded a large amount of ammonium chloride was added to the water into which the solutions in acid were poured, but this appears to have been without influence upon the purification or the character of the precipitation. The precipitates, after settling clear, were filtered upon asbestos, ignited and weighed, the original felts being employed in those cases in which asbestos was used in the first instance. Those marked with an asterisk were gathered in the first filtration upon paper, the paper being burned in the crucible in which solution of the precipitate was subsequently effected. The remainder were filtered originally upon asbestos.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.
(29)	0·5026 grm.	0·4746 grm.	0·0044 grm. —
(30)	0·5035 " *	0·4830 "	0·0022 " +
(31)	0·5016 "	0·4767 "	0·0024 " —
(32)	0·5025 "	0·4804 "	0·0050 " +
(33)	0·5046 " *	0·4829 "	0·0010 " +
(34)	0·5004 "	0·4825 "	0·0047 " +

These results show, evidently, that this process of purification is not satisfactory. It is possible that the losses observed may have been mechanical, and due to the violent action of the strong acid upon the water, but the excess in weight which is noticed in the majority of the determinations can only be attributed to residual contamination.

Certain experiments, on the other hand, in which the solvent action of sulphuric acid upon barium sulphate is utilized in a different manner resulted more favorably. When a solution of barium sulphate in sulphuric acid is evaporated to dryness, the

* Fres. Quant. Anal., vol. i, p. 547.

salt, as is well known, is deposited in large crystals, which can be filtered off as readily as sand. The following series of experiments show the result of an attempt to utilize this property of comparatively slow and large crystallization in purifying the precipitate Solution of the precipitate was effected as in the experiments described above, and the evaporation of the acid was effected over a matting of asbestos, or by means of a ring burner, in porcelain, which is preferable to platinum when the evaporation is carried on as slowly as is necessary. After the acid was completely evaporated, the crystals were washed upon a felt of asbestos, ignited and weighed. Five grams of potassium chloride and 10 cm³ of hydrochloric acid were added to the solution of barium chloride in each case.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.
(35)	0·5029 grm.	0·4796 grm.	0·0006 grm. —
(36)	0·5008 "	0·4783 "	0·0001 " +
(37)	0·5038 "	0·4810 "	0·0001 " —
(38)	0·5087 "	0 4861 "	0·0003 " +
(39)	0·5025 "	0·4795 "	0·0006 " +

These results are plainly good and satisfactory so far as concerns the purification of the salt, but, when the evaporation is conducted in the manner described, several hours are needed for the evaporation, and great care must be exercised to obviate the danger of snapping which becomes manifest in the later stage of the evaporation.

By the aid, however, of a Hempel evaporating burner* the operation can be finished safely, and with but little care, in the course of half an hour. The following determinations were made exactly like those of the last series, with the exception that the evaporation was effected by means of the Hempel apparatus.

	$BaCl_2 . 2H_2O$ taken.	$BaSO_4$ found.	Error.
(40)	0·5050 grm.	0·4824 grm.	0·0002 grm. +
(41)	0·5069 "	0·4838 "	0·0000 "
(42)	0·5041 "	0·4825 "	0·0021 " +
(43)	0·5021 "	0·4812 "	0·0018 " +
(44)	0·4033 "	0·4801 "	0·0005 " —

Though not an absolutely perfect process, the purification of barium sulphate by this method of solution and evaporation is evidently better, by far, than the old method of solution and reprecipitation by dilution.

The writer gratefully acknowledges his indebtedness to Prof. F. A. Gooch for many helpful criticisms and suggestions during the course of this investigation.

* Ber. d. deutsch. chem. Ges., xxi, p. 900.

ART. XXXIII.—*On Halotrichite or Feather Alum, from Pitkin County, Colorado;** by E. H. S. BAILEY.

A FEW months since a sample of a mineral was sent by J. J. Crippan, Esq., of Denver, Col., to the Laboratory of the State University for identification. He stated that it came from the Elk mountain range, and was found beside a ledge of "black iron ore." As no record can be found of the description or analysis of this mineral from an American locality, it has been thought that an investigation would be of value. The mineral is quite soft, has a white color, and a beautiful silky luster, resembling that of satin spar. Under the microscope and, to a certain extent, by unaided vision, the mineral appears to consist of capillary crystals arranged in parallel bundles. In some places the crystals, when viewed from the end, are of a green or copperas color. Under the microscope there appear to be attached to some of the fibers minute black particles. In picking the mineral for analysis these specks were eliminated as far as possible. There is only a slight tendency towards oxidation on the surface; and where this occurs the mineral is yellowish red.

The mineral is nearly all readily soluble in water and has a slightly acid, and very astringent taste. It fuses easily in the flame of a candle in its water of crystallization, and as the temperature increases it boils and finally leaves a reddish mass. If, however, the mineral be heated very gradually in a paraffin bath it does not melt or lose its form, but gradually loses its water. Afterwards, if heated nearly to redness, it retains its form, but gradually changes to a red color.

As it was noticed that much of the water was given off at a very low temperature, a quantity of the mineral was heated below 100° C., and, in fact, till just before the close of the experiment, below 85°, and the water thus driven off was collected in a calcium chloride tube and weighed. The mass was thus heated till no more water was given off at this temperature. 33·10 per cent of water was thus eliminated. The remainder of the water was driven off at a much higher temperature; very little, in fact, going off below 250° C.

As the mineral was not completely soluble in water and hydrochloric acid, the solution was evaporated to dryness and silica separated as usual. This silica, or an insoluble silicate, is probably not a proper constituent of the mineral, but so closely associated with it that even in the cleanest and most silky fibers it cannot be separated mechanically. The blowpipe reactions for iron are obtained. If the silky fibers be

* Read before the Kansas Acad. of Science.

dissolved even in cold water, the presence of some ferric salt can be detected by potassium sulphocyanate. The analysis of the mineral for ferric salts was made by dissolving in freshly boiled water in an atmosphere of carbonic acid gas, and afterwards titrating with sodium thiosulphate.

The analysis is as follows:

SiO_2 (and insoluble)	·42
SO_3	33·46
Al_2O_3	12·98
Fe_2O_3	1·60
FeO	5·19
MgO	·17
H_2O (expelled below 100° C.)	33·10
H_2O " above 100° C.)	12·94
	99·86

This is essentially a sulphate of alumina and ferrous oxide, with a part of the former replaced by ferric oxide, and a part of the ferrous oxide replaced by magnesia.

In composition it corresponds quite closely with the Hversalt of Forchhammer, from Iceland. This latter should be probably regarded as a variety of Halotrichite, as the difference in composition is very slight. In the manner of losing its water of crystallization there is an analogy between this mineral and other allied artificial salts; as, for instance, "Green Vitriol," which loses 6 molecules of water at 114° C. but retains the last molecule even at 280°.

Chem. Laboratory, Univ. of Kansas, Dec., 1890.

ART. XXXIV.—*On a new Serpent from Iowa;** by R. ELLSWORTH CALL.

THE subject matter of this brief notice is based upon four examples of a serpent which have passed into our hands during the past three years, or which have been loaned us for purposes of comparison. Aside from those differences which appear to us worthy of recognition as subspecific in value there is the added interest attaching to the finding of this form so far north and east of the range of the typical species. The typical form ranges, according to Garman,† "from Texas to Kansas;" it is also reported from southern Illinois‡ and from

* Read before the Iowa Academy of Science, January 1st, 1891.

† Samuel Garman, the Reptiles and Batrachians of North America, p. 32.

‡ H. Garman, in Bull. Ills. State Lab'y of Natural History, 1890, p. 188.

Ohio, which reports are the only ones mentioning it as occurring north of the Ohio River. The more eastern forms, as would appear from Mr. Garman's remarks, differ but little from the type that Hallowell had before him in drawing up his description; the chief differences being those of dimension, and the position of the eye with reference to the third and fourth supralabial plates.

To complete the record of the species, the following brief history of the type form is given. The form *lineatum* was described by Hallowell* and referred to his genus *Microps*,† in 1856. Four years later Cope separated it from the genus *Storeria* to which it had been referred by various authors, and made it the type of his new genus *Tropidoclonium*. Certain other forms have been included in the same genus but are now distinguished; with these we have here nothing to do.‡

I propose, therefore, to describe this form under the name of

Tropidoclonium lineatum Iowæ, subsp. nov.

Reptile small; head hardly distinguished from body; eye small, placed over the third and fourth labial plates, circular; head flat posteriorly but before the eyes slightly convex; mouth large, direct to the end of the third labial, thence gently curved to the angle; snout rounded, blunt; head shields nine, frontals quite twice the size of the prefrontals, rostral rather large, somewhat broader than high, blunt or rounded, triangular; nasal one, grooved below the nostril, longer than broad; loreal small, elongate, low, its upper margin on a direct line with the center of the eye and the nostril; preorbital one, excavated, forming a shallow pit in front of eye; postorbitals two, small, subequal, the upper extending a short distance in front of the posterior margin of the eye; one temporal on the left side, two on the right; labials seven, the sixth large, not extending to the edge of lip, but wedged in between the fifth and seventh; the fifth labial the largest; infralabials six, the fourth largest; gulars in three rows; scales in nineteen rows; the small dorsal scales nearly all slightly notched; gastrosteges 143 to 148.

The general ground color above is light chocolate, with a median light—whitish or straw-yellow—stripe extending from the base of occipitals to tip of tail, and occupying all the median scale, and half of the row adjoining on each side;

* Proc. Philad. Academy of Nat. Sci., p. 241, 1856.

† The generic name was bestowed in reference to the very small eyes. This generic name had, however, been preoccupied in the *Reptilia* by Wagler, in 1828, by Agassiz in the Fishes, in 1833; and had also been used in 1823 and 1833 to name genera in the *Coleoptera* and the *Hymenoptera* respectively.

‡ *Vide* Cope in Proc. Philad. Acad. of Nat. Sci., 1860, p. 76; also in Proc. U. S. Nat'l Mus., 1888, p. 391.

there is a much broader lateral stripe, extending from the labials, which are included, to the vent, whence, to tip of tail, the color is uniform chocolate-brown. This lateral stripe is one and one-half scales broad. The base of each of the lowermost dorsal scales is black, which color, however, is subepidermal. The head is inconspicuously mottled with small, irregular, black spots, but the general color is light-brown. The base of each alternate scale, in the fifth dorsal row, is black, causing a peculiar spotted, linear, appearance. The belly is white, with a double row of deep black spots, largest on the middle where, also they are confluent, but entirely wanting on the first two gasterosteges; elsewhere they are present to the end of the tail, but do not at any point reach the edge of the ventral plates.

Of the specimens mentioned in the following table, in which are given all measurements that are thought to be useful, the two first specimens were taken at Ames, Story County, Iowa, the two remaining ones, at Des Moines; both localities are near the very center of the State.

	1.	2.	3.	4.
Gasterosteges	146	148	143	145
Scales, rows	19	19	19	19
Subcaudals, pairs	31	29	18*	35
Length, in inches	14	12·5	8·625*	10·875
Tail, in inches	1·625	1·375	----*	1·375
Tail, times in length	8·61+	9·09	----*	7·89+
Eye, in head	5	5·5	4·5	5·25
Anal plate	entire	entire	entire	entire

From typical *T. lineatum* this variety differs in the number of rows of dorsal scales, in the larger eye, greater size, constant lighter color, in the characters of the markings of the gasterosteges, in the shape, size and grooving of the nasals, and in the number and arrangement of the gulars. In other respects it is closely like the type of Hallowell's form.

Of the specimens which have come under notice, and which have been used in drawing up this description, two may be seen in the museum of the Iowa Agricultural College, at Ames, Iowa; one in the collections of the Indiana University, Bloomington, and one in the West High School, Des Moines, Iowa. As above noted the distribution is thus far restricted to central Iowa.

Des Moines, Iowa, January 5th, 1891.

* This specimen was pathologic, having lost the greater portion of the tail.

ART. XXXV.—*On Crystallized Azurite from Arizona;* by O. C. FARRINGTON.

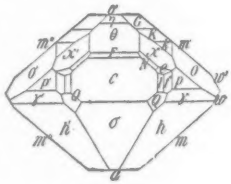
CRYSTALS of azurite from Arizona, remarkable for their number and brilliancy, have for a long time been abundant in collections, but so far as we know no detailed crystallographic study has yet been made of them. The monograph of Schrauf published in 1871,* contains no reference to any specimens from this locality, the only American crystals mentioned being some from Venezuela. Mr. Oliver W. Huntington has described† crystals from Clifton, Arizona, elongated in the direction of the orthodiagonal, a habit which will be referred to later. On these crystals twelve forms were identified, but the crystals, he states, were not suitable for accurate measurement. No further study of the Arizona crystals has been made as far as known.

With a view, therefore, of ascertaining the chief types or habits into which these crystals group themselves as compared with European azurites, and of obtaining as much data as possible toward establishing an exact axial ratio, the writer has made an investigation of them, with material very kindly placed at his disposal by Profs. E. S. Dana and S. L. Penfield. Altogether twenty-one forms were observed on the Arizona crystals, and these are given in the following table, the four marked by an asterisk being new. Previous to this a total number of 54 forms had been observed. The symbols are given in accordance with the position for azurite adopted by Haidinger, Miller and Dana.

c, 001, *O*	θ, $\bar{1}01$, 1-$\bar{1}$	*h*, 221, −2	*o*, $\bar{2}41$, 4-$\grave{2}$
a, 100, $\acute{i}$-$\bar{1}$	η, $\bar{3}02$, $\frac{3}{2}$-$\bar{1}$	γ, 121, −2-$\grave{2}$	**G*, $\bar{3}21$, 3-$\frac{3}{2}$
m, 110, *I*	*l*, 023, $\frac{2}{3}$-$\acute{i}$	**N*, $\bar{1}47$, $\frac{1}{4}$	**K*, $\bar{1}\bar{2}\cdot10\cdot5$, $\frac{1}{5}$-$\frac{2}{5}$
W, 120, $\acute{i}$-$\grave{2}$	*f*, 011, 1-$\acute{i}$	*x*, $\bar{1}11$, 1	
σ, 101, −1-$\bar{1}$	*p*, 021, 2-$\acute{i}$	*k*, $\bar{2}21$, 2	
F, $\bar{2}07$, $\frac{2}{7}$-$\bar{1}$	**Q*, 223, −$\frac{2}{3}$	*e*, $\bar{2}45$, $\frac{4}{5}$-$\grave{2}$	

Fig. 1 shows a basal projection of these forms, from which the principal zonal relations can be determined. The size given to each face indicates its relative importance, and it will be noted that but a small number of forms occur in the negative quadrants.

1.

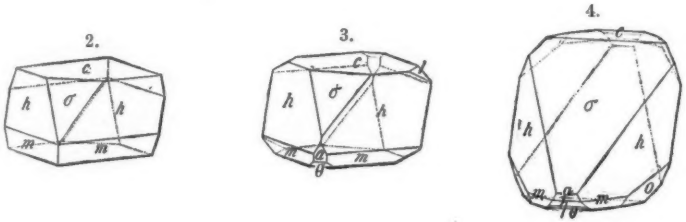


It was found that all of the crystals examined could be referred to one or the other of four principal habits, which may be designated as the pyramidal, prismatic, dome-like and lath-like habits, the

*Sitzungs Berichte, Vienna, Akad., June and July, 1871.
† Proc. Amer. Acad. Arts and Sci., 1885.

two latter being produced by the predominance of the clinodomes and orthodomes respectively.

Pyramidal Habit.—Figs. 2, 3 and 4. This habit, which is characterized by the predominance of the pyramid h, 221, was found to prevail in by far the larger number of the

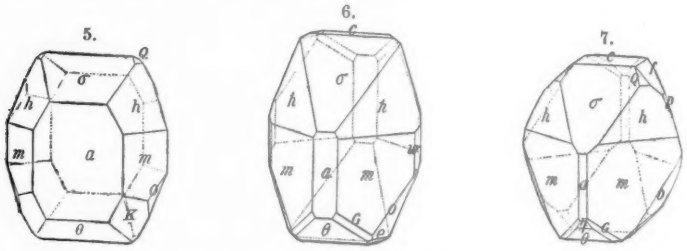


specimens examined. The crystals vary much in size, are usually attached by the basal plane, and the faces c, h, m, and σ, are always prominent. Each of these can usually be recognized at a glance, m and h by the small angle (19° 57′) which they make with one another, c by the striations commonly present parallel to the edge ca or cb; and σ from the angle of nearly 45° which it makes with the adjoining faces. Where other faces are present, fig. 3, they are always so small that they could not be confounded with those just mentioned. In the crystal shown in fig. 4, the face σ so largely predominates as to give a tabular appearance. A crystal of similar shape from Porto Cabello, Venezuela, is figured by Schrauf (Tafel II, fig. 23) and, as he remarks, from the similarity of the angles $c\sigma$ and σh, the crystal at first glance appears to be of a rhombohedral type with σ as the basal plane. Aside from the one just mentioned and a crystal from Cornwall figured by Zippe, I have found no other figures of azurite where the pyramid h predominates. This habit therefore may be considered peculiar to the Arizona azurites. Though a large number of crystals of this habit were examined, none were found suitable for accurate measurement. The edges are generally sharp and the faces fairly bright, but always so curved or warped as to give a long series of reflections of the signal on the reflecting goniometer.

Prismatic Habit.—Figs. 5, 6 and 7.

The crystals shown in these figures were all from a Morenci, Arizona, specimen. Some have a comparatively large size, the one shown in fig. 6, being 10^{mm} in length. They were usually attached by the orthopinacoid which varied in the amount of its development, but where large, gave to the crystals an appearance very like the upper portion of the simple cut brilliant, the

orthopinacoid making up the table and the surrrounding faces the bezel, fig. 5. Another peculiarity is that all the prominent



angles are near 45° or 90°. On this crystal, the new form K, $\bar{1}\bar{2}\cdot10\cdot5$, $\frac{1}{5}\frac{2}{5}\frac{5}{5}$, was observed and its symbol determined from its position in the zone ah, and the following measurements.

	Meas.	Calc.
$K \wedge a$, $\bar{1}\bar{2}\cdot10\cdot5 \wedge \bar{1}00$	39° 55′	39° 48′
$K \wedge h$, $\bar{1}\bar{2}\cdot10\cdot5 \wedge 221$	95° 57′	96° 16′
$K \wedge m$, $\bar{1}\bar{2}\cdot10\cdot5 \wedge \bar{1}10$	19° 38′	18° 53′

From the close relation of this symbol to that of the form G, $\bar{3}21$, which occurs on other crystals of this habit, it was at first thought that they should be the same, but this face was found to lie outside the zone $m\theta$, and though it was impossible to obtain accurate measurements, all varying from 1° to 2°, the symbol given accords so well with the mean of all, that there can be little doubt of its correctness. The crystal shown in fig. 6 is like the one last mentioned, except in being more elongated in the direction of the vertical axis and in having the orthopinacoid less prominently developed. In fig. 7 the general habit is the same but the crystal is more highly modified. The latter represents a type of common occurrence, the crystals never being completely developed and with the faces often distorted in size and shape, so that they appear as clusters of faces of nearly equal size, without apparent symmetry. They are usually attached along the zone of clinodomes, the basal plane and domes showing striations parallel to the edge cf.

In figs. 6 and 7 the new forms Q, $223,-\frac{2}{3}$ and G, $\bar{3}21$, $3-\frac{3}{2}$ will be observed.

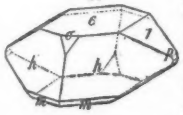
The form Q also occurred on the lath-shaped crystals, and as more accurate measurements could be made on these, will be described under that head. The symbol of G was determined from its occurrence in the zones ah and $m\theta$ and from the following measurements.

		Meas.	Calc.
$G \wedge m$,	$\bar{3}21 \wedge \bar{1}10$,	18° 36′	18° 53′
$G \wedge \theta$,	$\bar{3}21 \wedge \bar{1}01$,	38° 51′	38° 45′
$G \wedge a'$,	$\bar{3}21 \wedge \bar{1}00$,	33° 30′	33° 35′
$G \wedge h$,	$\bar{3}21 \wedge 111$,	102° 17′	102° 29′

Here again, accurate measurements could not be obtained, since, owing to striations and oscillatory combinations, the reflections of the signal were always an unbroken band of from 1° to 4° in length. The measurements given were taken as nearly as possible from the middle of these bands. The form G occurs as a more or less rounded truncation of the edge $m\theta$. It is interesting to note that in the Chessy azurites, according to Schrauf, a like truncation of the edge between the hemidome and prism occurs, but in this case in the negative quadrant, that is, the edge $m\sigma$.

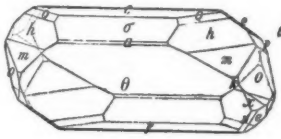
Dome-like habit. Fig. 8.—All the crystals of this habit were found on one specimen, associated with the new mineral spangolite, which is supposed to have come from near Tombstone, Arizona. They are all characterized by being slightly lengthened out in the direction of the clinodiagonal, and by the predominance of the clinodome, l, 023. Striations parallel to the edge cl are common and serve for identifying the faces. A habit similar to this, occurring in the Chessy azurites, is figured by Lévy.*

8.

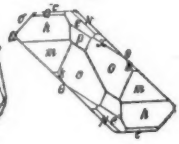


Lath-like habit. Figs. 9 and 10. — Crystals of this habit occur at the Longfellow Mine, Arizona, and all show the same peculiarity of form, due to a lengthening out in the direction

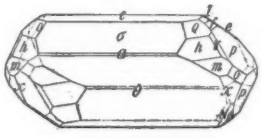
9.



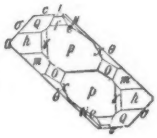
9*a*.



10.



10*a*.



of the orthodiagonal and the remarkable development of the orthodome θ. Two crystals were selected as the most nearly

* Atlas, Pl. 64, fig. 25

perfect of these; they were about 5mm in width by 2mm in thickness. In the direction of their length, both were incomplete, the attachment at one end having prevented the development of faces there. Doubly terminated crystals occur, however, where the relative length is about like figs. 9 and 10.

On the crystals selected the new forms Q, $223, -\frac{2}{3}$ and N, $\bar{4}47$, $\frac{4}{7}$, were observed. The measurements given by the former were very accurate and will be found in the subsequent tables. These, together with its position in the zones *al* and *cm*, sufficiently determine its symbol. Krenner and Franzenau are credited* with having observed this form on crystals from Utah, but no angles are given. The form N has its position in the zone *cm* and $e\theta$, but on account of its blending more or less with the face θ only approximate measurements could be obtained from it in the latter zone. The best obtained were as follows:

		Meas.	Calc.
$N \wedge c$,	$\bar{4}47 \wedge 001$,	38° 33′	38° 34′
$N \wedge x$,	$\bar{4}47 \wedge \bar{1}11$,	16° 20′	16° 17′
$N \wedge \theta$,	$\bar{4}47 \wedge \bar{1}01$,	27° 1′	28° 31′
$N \wedge e$,	$\bar{4}47 \wedge \bar{2}45$,	13° 29′	12° 8′

Figs. 9*a* and 10*a* represent the projection of figs. 9 and 10 upon the plane of the clinopinacoid, by which the zonal relations of the faces are more clearly shown. The close similarity noted by Schrauf of the crystalline form of azurite to that of epidote, amounting, in his view, to a kind of isomorphism, is quite strikingly shown in these crystals, both in their being lengthened out in the direction of the orthodiagonal and in the prominence of the pyramid o, $\bar{2}41$, and the clinodome, p, 021, each of which correspond in angles to prominent faces in epidote. While I see no reason for regarding the similarity in the crystalline development of the two minerals as anything more than a coincidence, the coincidence is certainly remarkable.

The faces on the free ends of these crystals were nearly all very perfect, and gave sharp, well-defined reflections of the signal, so that the measurements obtained from them possess a high degree of accuracy. The following, taken from the crystal represented in fig. 9, were selected as fundamental, each measurement having been made with great care seven times on the reflecting goniometer, using the high ocular.

$o \wedge o$	$\bar{2}41 \wedge 24\bar{1} =$	65° 5′
$h \wedge h$,	$221 \wedge \bar{2}2_ =$	105° 39′
$h \wedge o$,	$221 \wedge \bar{2}41 =$	75° 56′

The axial ratio deduced from these is:

$$\dot{a} : \bar{b} : \dot{c} = \cdot 85676 : 1 : \cdot 88603. \quad \beta = 87° 36′ 36″ = 001 \wedge 100.$$

* Zeitschr. Kryst., vol. viii, p. 53.

In the position adopted by Schrauf the vertical axis is given double the length of that in our position. Taking, therefore, one-half the value which he gives to c, his axial ratio is:

$$\dot{a} : \bar{b} : \dot{c} = \cdot 85012 : 1 : \cdot 88054. \quad \beta = 87° 36'$$

It will be seen that these ratios differ but little, the values for β being almost identical, while those for $\dot{a}$ and c agree to the third decimal place. The author's value for $\dot{a}$ is supported by several very accurate measurements of the prism $m \wedge m$, which in every case showed a close approximation to the angle 81° 8′ instead of 80° 42′ as given by Schrauf. Whether this variation is to be regarded as a fundamental difference in the prismatic angle of the crystals from the separate localities or, on the other hand, as so small as to be within the limits of error in observation, I cannot say. More data are needed for deciding the question. The most satisfactory measurements that could be obtained for judging of the correctness of the value assigned to $\dot{c}$, were those of $c \wedge p$, $001 \wedge 021$, and $p \wedge p$, $021 \wedge 02\bar{1}$. The measured and calculated angles compare as follows:

		Calculated.		Measured.	
		Farrington.	Schrauf.	No. 1.	No. 2.
$c \wedge p$,	$001 \wedge 021$	60° 33′	60° 24′	60° 29′	60° 30′
$p \wedge p$,	$021 \wedge 02\bar{1}$	58° 56′	59° 12′	59° 1′	59° 6′

From these it would seem that the true value of $\dot{c}$ is about a mean between that given by Schrauf and by the author. Here, again, more accurate measurements are needed.

In Table I the measurements of all the prominent zones in these crystals are given and, for comparison, their values as calculated from the author's axial ratio and from that of Schrauf. Where measurements of other crystals were of sufficient accuracy to make them trustworthy, these have been put in the column headed "Other measurements;" but, though a large number were studied in the hope of obtaining such, only a few were found. Tables II and III give the calculated and measured values of the angle of each face upon the pinacoids c, 001, and a, 100. Owing to the imperfect development of these pinacoids in the two best crystals, the measurements given do not have equal significance with those of the preceding table. They are, however, the angles most commonly met with in the Arizona crystals. The clinopinacoid b, 010, was in no case observed. These tables show, as a rule, close agreement of the calculated and measured angular values, and likewise but small differences in the calculated values given by Schrauf and by the author. The chief variations that arise in the latter, correspond to the differences in the prismatic angle which have been previously mentioned. It is to be hoped

that from this or other American localities, more crystals suited for exact measurement may be obtained and thus furnish addi-

TABLE I.

	Calculated.		Measured.		
	Farrington.	Schrauf.	Crystal No. 1. (Fig. 9.)	Crystal No. 2. (Fig. 10.)	Other measurements.
$c \wedge Q$, 001 ∧ 223	41° 24′	41° 21′	41° 22′	41° 20′	------
$Q \wedge h$, 223 ∧ 221	26 50	26 51	26 51	26 49	26° 2′
$h \wedge m$, 221 ∧ 110	19 57	19 58·5	19 57	19 59	19 56
$m \wedge k$, 110 ∧ 22$\bar{1}$	20 23	20 24·2	20 23	------	------
$m \wedge x$, 110 ∧ 11$\bar{1}$	36 56	36 59·2	37 0	37 4	------
$k \wedge x$, 22$\bar{1}$ ∧ 11$\bar{1}$	16 33	16 35	16 37	------	------
$x \wedge N$, 11$\bar{1}$ ∧ 44$\bar{7}$	16 20	16 19·5	16 17	16 13	------
$N \wedge c'$, 44$\bar{7}$ ∧ 00$\bar{1}$	38 33	38 31	38 34	38 33	------
$a \wedge h$, 100 ∧ 221	43 56	43 45·5	43 50	43 58	43 50
$h \wedge \gamma$, 221 ∧ 121	18 11	18 12·5	------	18 15	------
$\gamma \wedge p$, 121 ∧ 021	26 42	26 51	------	26 37	------
$h \wedge p$, 221 ∧ 021	44 53	45 4.5	44 52	44 52	44 46
$p \wedge k$, 021 ∧ $\bar{2}$21	46 6	46 16	46 3	------	------
$k \wedge a'$, $\bar{2}$21 ∧ $\bar{1}$00	45 5	44 55	45 19	------	------
$c \wedge e$, 001 ∧ $\bar{2}$45	39 50	39 44	39 46	39 46	39 36
$e \wedge o$, $\bar{2}$45 ∧ $\bar{2}$41	37 36	37 39·5	37 39	37 40	37 33
$o \wedge W$, $\bar{2}$41 ∧ $\bar{1}$20	13 46	13 49·5	------	------	12 24
$o \wedge \gamma$, $\bar{2}$41 ∧ $\bar{1}$21	39 32	39 40	------	39 31	------
$\gamma \wedge c'$, $\bar{1}$21 ∧ 00$\bar{1}$	63 2	62 56·5	------	63 3	------
$x \wedge o$, $\bar{1}$11 ∧ $\bar{2}$41	28 26	28 26 5	29 1	28 32	------
$o \wedge p$, $\bar{2}$41 ∧ 02$\bar{1}$	51 10	51 25·8	51 11	51 16	------
$p \wedge e$, 02$\bar{1}$ ∧ $\bar{2}$45	30 45	30 48	30 46	30 51	------
$c \wedge l$, 001 ∧ 023	30 33	30 24	30 27	30 31	30 38
$l \wedge f$, 023 ∧ 011	10 58	10 57	------	10 58	------
$f \wedge p$, 011 ∧ 021	19 1	19 3	------	19 0	------
$p \wedge p$, 021 ∧ 02$\bar{1}$	58 56	59 12	59 1	59 6	------
$p \wedge c'$, 02$\bar{1}$ ∧ 00$\bar{1}$	60 32	60 24	60 29	60 30	------
$a \wedge f$, 100 ∧ 011	88 12	88 12	------	88 16	------
$f \wedge x$, 011 ∧ $\bar{1}$11	38 26	38 33	------	38 26	------
$x \wedge a'$, $\bar{1}$11 ∧ $\bar{1}$00	53 22	53 15	------	53 18	------
$a \wedge Q$, 100 < 223	57 47	57 42	------	57 50	------
$Q \wedge l$, 223 ∧ 023	30 9	30 13·8	------	30 6	------
$l \wedge a'$, 023 ∧ $\bar{1}$00	92 4	92 4·2	------	92 0	------
$m \wedge o$, $\bar{1}$10 ∧ $\bar{2}$41	23 50	23 56	23 51	23 50	23 53
$o \wedge p$, $\bar{2}$41 ∧ 021	32 55	32 54	32 48	32 49	------
$m \wedge p$, $\bar{1}$10 ∧ 021	56 45	56 50	56 38	56 39	------

tional data by which to accurately establish the angular values in accordance with which the crystal forms of this interesting and beautiful mineral unite.

In conclusion, the writer desires to acknowledge with thanks, the kindness of those who have furnished him with material

TABLE II.—Angles on basal plane, *c* (001).

		Calculated.		Measured.		Other measurements.
		Farrington.	Schrauf.	Crystal No. 1.	Crystal No. 2.	
m,	110	88° 11′	88° 10·3′	88° 10′	88° 9′	88° 6′
l,	023	30 33	30 24	------	30 31	------
f,	011	41 31	41 21	------	41 28	------
p,	021	60 33	60 24	60 29	60 30	------
Q,	223	41 24	41 21	41 22	41 20	------
h,	221	68 14	68 12	68 10	68 9	68 13
γ,	121	63 2	62 56·5	------	63 3	------
e,	$\bar{2}45$	39 50	39 44	39 46	39 46	------
o,	$\bar{2}41$	77 26	77 23·5	77 24	77 26	------
N,	$\bar{4}47$	38 33	38 31	38 34	38 33	------
x,	$\bar{1}11$	54 53	54 50·5	54 51	54 47	------
k,	$\bar{2}21$	71 26	71 25·5	71 27	------	------
a,	100	87 37	87 36	------	87 38	87 36
σ,	101	44 44	44 46	44 41	44 41	44 42
F,	$\bar{2}07$	16 38	16 40	16 36	------	------
θ,	$\bar{1}01$	47 12	47 15	47 9	47 13	------
η,	$\bar{3}02$	58 53	58 56·5	------	------	58 54

TABLE III.—Angles on the orthopinacoid, *a* (100) and *a′* ($\bar{1}$00).

		Calculated.		Measured.		Other measurements.
		Farrington.	Schrauf.	Crystal No. 1.	Crystal No. 2.	
m,	110	40° 34′	40° 21′	40° 34′	40° 33′	40° 30′
W,	120	59 43	59 41	------	------	60 17
l,	023	87 56	87 55·8	------	87 56	------
f,	011	88 12	88 12	------	88 16	------
p,	021	88 50	88 49	88 52	88 50	------
σ,	101	42 53	42 50	42 46	42 57	42 56
Q,	223	57 47	57 42	57 40	57 50	------
h,	221	43 56	43 45·5	43 50	43 58	------
γ,	121	62 7	61 58	------	62 12	------
x,	$\bar{1}11$	53 22	53 15·5	53 31	53 18	------
k,	$\bar{2}21$	45 5	44 55	45 19	------	------
G,	$\bar{3}21$	33 35	33 26	------	------	33 30
K,	$\bar{1}\bar{2}\cdot10\cdot5$	39 48	39 37	------	------	39 55
F,	$\bar{2}07$	75 45	75 44	75 56	------	75 47
θ,	01	45 12	45 9	45 20	45 12	------
η,	$\bar{3}02$	33 30	33 27·5	------	------	33 29

for the work, and the valuable assistance and advice which have been generously rendered him by Prof. S. L. Penfield.

Mineralogical Laboratory of the Sheffield Scientific School, June, 1890.

ART. XXXVI.—*On the Occurrence of Xenotime as an Accessory Element in Rocks;* by ORVILLE A. DERBY.

IN the examination of the heavy residues obtained by concentration in the *batêa*, or Brazilian miner's pan, of decomposed, or crushed, samples of a large number of Brazilian crystalline rocks, the rare mineral xenotime has been found to be a tolerably constant accessory of one group, viz: the muscovite granites. In comparison with the biotite, amphibole and pyroxene rocks, the muscovite rocks are comparatively rare in Brazil and in the present investigation no opportunity has offered for testing any of a gneissoid type. The samples examined represent an area extending from Ceara on the north to Rio Grande do Sul on the south, the greater portion being from the central part of this area in the States of Rio de Janeiro, São Paulo and Minas Geraes. As regards their geological occurrence the greater number are from small dykes cutting gneiss or metamorphosed (Cambrian?) schists, a few being from large bosses which, in one case at least, are newer than the schists. These masses are, for the most part, totally decomposed to kaolin, and in some cases have been referred to the muscovite granites from the inspection of the decomposition products alone, so that it is possible that some highly feldspathic rocks of other types, or in which the muscovite is secondary after biotite, have been included. It should be noted that the ones subject to this suspicion are included in the small number that failed to yield xenotime, while in others all the usual accessories were uncommonly rare, and the absence of the mineral may, perhaps, be due to a deficiency in the quantity washed. In these tests about a cubic decimeter was treated and in several instances some of the heavy accessories were so rare that only two or three microscopic grains could be detected in the residue. The usual associates are zircon and monazite, the second rarely, the first never failing to appear in a residue containing xenotime. As the lighter and the iron-bearing accessories, such as tourmaline, garnet, magnetite and titaniferous iron were removed by the use of heavy liquids and the electro-magnet in the preparation of the residues for microscopic examination, no record was kept of their occurrence, though, with the exception of garnet, they were almost constantly found.

The xenotime occurs in the well known octahedral form with the prismatic faces usually barely susceptible. The elongated crystals with highly developed prismatic faces that characterize this mineral in the diamond gravels of various Brazilian local-

ities* have not been observed in any of the washings from material obtained *in situ*. In one case the octahedral edges are modified by faces of the diametric pyramid 1-$\bar{i}$ not cited in any of the descriptions of the mineral that are at hand for consultation. At one locality the characteristic intergrowth with zircon occurs and first led to a suspicion that certain minute octahedral grains apparently too small for any attempt at mineralogical identification might prove to be xenotime, a suspicion that has been fully confirmed by microchemical and optical tests, the last of which were kindly made by Dr. Eugene Hussak.

The crystals rarely attain a length of 1^{mm}, the usual size being about $\frac{1}{4}^{mm}$. In a few localities they are perfectly transparent, yellow or colorless, with highly polished faces. Generally, however, the faces are roughened through alteration, which renders the whole crystal, with the exception of the extreme edges, milk-white and more or less opaque. Owing to their flattened pyramidal form they generally rest in the microscopic preparation in such a position as to readily give the interference cross in convergent polarized light and permit the determination of the positive character of the double refraction and thus prevent confusion with anatase, a frequent companion difficultly distinguishable in some of its forms from xenotime. Samples from 21 different localities have been tested, of which 2 are in Ceara, 7 in Rio de Janeiro, 6 in São Paulo, 5 in Minas Geraes, and 1 in Rio Grande do Sul. In this enumeration a number of small dykes, all affording xenotime, in São Paulo are excluded since they are presumed to be apophyses of a large boss already included. Of these 21 localities 14, or $66\frac{2}{3}$ per cent, gave xenotime always accompanied by zircon and in all but three cases by monazite. Of the 7 which gave no xenotine, 3 afforded such insignificant residues (even the omnipresent zircon failing in one) that a larger amount of material should be tested before a positive conclusion is reached, while two others are probably not true muscovite granites. One of the latter is a small dyke near the Tingua mass of nepheline syenite, from which it is possibly an apophesis and differs from any authentic granite residue yet examined in the character of its zircons, among which geniculated twins occur. The other is a granitic mass in which the muscovite may be secondary after biotite. Eliminating these and one xenotime-bearing rock which appears to be a biotite gneiss, the proportion stands as 15 to 13. That is to say, $86\frac{2}{3}$ per cent of the undoubted muscovite granites that have been sufficiently tested have afforded xenotime, which is thus as constant as any other accessory except zircon. In the biotite gneiss above referred to

* See Gorceix, Sur la xenotime de Minas Geraes (Brésil), C. R., cii, 1886, pp. 1024–1026.

the xenotime occurs with an abundance of monazite in a thin black totally decomposed feldspathic layer intercalated in a black schistose highly micaceous gneiss, which is poor in accessories and, like most of the gneiss and granites in the district (about Petropolis), affords only zircon. This difference and the general character of the layer suggests a suspicion that, instead of a segregation as was presumed without a very close examination, it may prove to be a dyke of muscovite granite modified by dynamo-metamorphism. It is on the xenotime crystals of this layer that diametric faces were observed. Two of the São Paulo localities are of muscovite-biotite granites, one of which forms a considerable boss erupted through Cambrian (?) schists. It is noticeable that these biotite-bearing rocks afford extremely abundant residues of monazite and xenotime, while the zircon is unusually rare. A dyke of lithia-mica granite with muscovite, in the vicinity of one of these bosses, is free from phosphatic minerals, but contains rare grains of cassiterite associated with zircon.

The presence of this yttrium phosphate appears to be in some way dependent on that of potash, since only in the somewhat doubtful case of Petropolis has it been observed outside of the potash-granites, although hundreds of residues have been examined. The same cannot be said of its almost inseparable companion, the cerium phosphate (only three xenotime-bearing residues failed to show monazite, and this, perhaps, owing to deficiency in the quantity of rock washed), which has proved to be very frequent, though less constant, in the biotite gneiss and granites, rare in those containing amphibole. Magmas rich in soda, represented by phonolites, nepheline and augite-syenites, seem to be unfavorable to both minerals, as neither have been found in the dozen or more residues examined. The other companion, zircon, on the contrary, rarely fails to appear in the crystalline rocks, except in the most accentuated basic types—such as diabase, basalts, etc. It may be noted further that in the rocks rich in potash, as indicated by the presence of muscovite, the zircon and monazite in the residues from decomposed material are almost always somewhat altered, being corroded, whitened, and more or less opaque, whereas, in the biotite rocks they rarely show the slightest signs of alteration. The latter observation applies also to the zircons of the soda-bearing rocks as far as these have been examined.

The almost constant occurrence of the cerium and yttrium phosphates, monazite and xenotime, in the Brazilian rocks suggests the hypothesis that they will be found in similar rocks all over the world. A recent visit to the United States has enabled me to test this hypothesis on a small number of North American granites and gneisses. Drift bowlders picked up in

Central New York gave a very characteristic residue of zircon with yellow grains that look exceedingly like monazite, though as I have not as yet been able to subject them to the necessary optical and chemical tests, the identification is not complete. A specimen of granite from Westerly, Rhode Island, kindly furnished by Prof. J. F. Kemp, gives an extremely abundant heavy yellow residue similar in appearance to the Brazilian monazite and, like it, showing the absorption band of didymium when examined under the microscope with the spectroscopic eye-piece.* An experiment with the latter apparatus made for me by Prof. Simon Gage of Cornell University proves that the characteristic absorption bands of didymium and of erbium can be readily perceived on microscopic grains (presumably also in thin rock section, though unfortunately none were at hand for testing) of monazite and xenotime, and thus a very simple and rapid method of detecting minerals containing the cerium and yttrium group of elements is afforded.

ART. XXXVII.—*On the Magnetite Ore Districts of Jacupiranga and Ipanema, São Paulo, Brazil;*† by ORVILLE A. DERBY.

Two ore districts that have lately been investigated by the São Paulo Geological Survey afford instances of what appears to be a hitherto unnoticed mode of occurrence and association of magnetic iron ores. The districts in question, which agree so closely that they serve to mutually explain each other, are situated about 150 kilometers apart on opposite sides of the Serra do Mar. That of Jacupiranga is in a region of comparatively low hills at the extremity of a high ridge of the Serra do Mar system, rising from the low plains of the coast and of the lower course of the Ribeira (or Iguape) river. The Ipanema ore deposits are in the center of an isolated mountain block, bounded by fault planes that rise some 300 meters above a plain that is essentially horizontal with a mean elevation of about 700^{m}. The basement rocks in both districts are

* An examination, not yet concluded, kindly made by Dr. G. H. Williams, seems to prove that this cannot be monazite. Whatever it may prove to be, it illustrates the value of the batea in petrographical study, as by its use an abundance of a rare and interesting accessory was obtained with about ten minutes' work.

† This paper is an English abstract of two reports prepared in the Portuguese language for publication in the Boletina da Commissão Geographica e Geologica de São Paulo, by the present writer, with the coöperation, in the case of the Ipanema district of Dr. Luiz Gonzaga de Campos. The petrographical work has been carefully revised by Dr. Eugen Hussak while Mr. Henry E. Bauer, an able amateur geologist and volunteer assistant, has furnished much valuable material and information regarding the Jacupiranga district.

the same and identical with the characteristic formation of the intervening position of the Serra do Mar, which in this region is made up principally of a series of more or less completely metamorphosed schists cut by numerous and extensive eruptions of granite. These schists are mainly clay-slates, but more highly metamorphosed argillaceous strata appear and more rarely quartzites. One or more beds of limestone, generally black and amorphous but frequently altered to marble, form a very characteristic and presistent member of the series. As no fossils have yet appeared the age of this series cannot be made out, but it is certainly pre-Devonian and presumably Cambrian. The plain surrounding the Ipanema mass, as well as a portion of the block itself, is of late Carboniferous or Permian age. The eruptive rocks described below while in the main confined to the Cambrian (?) area have been found at a few points cutting the Carboniferous strata. At Jacupiranga on the contrary nothing with the exception of eruptive rocks has been recognized between the ancient formation and the modern alluvial deposits, so that there is no criterion for determining the age of the eruptions.

For purposes of study the Jacupiranga district far excels that of Ipanema not only in the variety of its rocks, but also in their state of preservation.* The one district proper includes an area of 30–40 square kilometers of nearly rectangular form lying to the west of the small river Jacupiranga, and extending well over towards the great parallel stream, the Ribeira, which below its great bend, receives the Jacupiranga. The divide between the two streams consists of gneiss and granite flanked on each side by Cambrian (?) schists cut by a great variety of eruptive rocks. These last include various types of orthoclase-pyroxene, orthoclase-nepheline, and plagioclase-nepheline rocks, nephelinites, teschinites, vosgesites, basalts, etc. In the study of the field relations of these various groups, made in great part by Mr. Bauer, in part by the writer with the assistance of Drs. Campos and Hussak, an intimate connection between the most of them and with the iron ore, has been directly proven in many cases and is strongly suspected in others.

The ore district proper is for the most part heavily wooded and covered with a rich dark soil containing everywhere a greater or less amount of magnetite in grains or blocks ranging in size from the finest sand up to masses of the size of a man's head. The predominant rock, as seen in the deeper parts of the cuttings, is a dark-brown or black schist in inclined layers with an abundance of mica flakes along the division

* Unusual facilities for examination were afforded by the operations (since suspended), for the erection of iron works. These included several large excavations for foundations and the grading of six kilometers of tramway affording a nearly continuous section across a large portion of the district.

planes, which give it the aspect of a mica schist. Sections from the inner portion of one of these mica-covered slabs (the outer micaceous portion is too friable for section cutting), show the rock to be composed almost exclusively of irregular grains of violet-colored titaniferous pyroxene with, as accessories, an abundance of iron minerals (magnetite and titaniferous iron), rare grains of perofskite and milky white grains, in part apatite, in part a zeolitized silicate. No mica can be seen in these sections. Higher up in the cuttings where the rock is so friable as to readily crumble in the fingers, the mica becomes more abundant, lining not only the original planes of schistosity but all secondary divisional planes including those between the partially disaggregated grains of pyroxene. The origin of the mica from the weathering of the pyroxene is perfectly clear, and higher up in the cuttings the rock is seen to lose entirely its lithoid character, and to pass to a yellow clay composed exclusively of decomposed mica flakes.* This in turn passes to a dark-red soil which, like the yellow micaceous clay affords, on washing, the characteristic residue of the sound pyroxene rock, viz: iron minerals, apatite and perofskite.

At many points throughout the district, the iron minerals in the rock above described rise from the rôle of an accessory to that of an essential element giving layers composed of various proportions of pyroxene and magnetite which, by the disappearance of the pyroxene, pass to a pure iron ore. This enrichment in iron is accompanied by the total disappearance of the white silicate, and a diminution in the quantity of perofskite. In specimens of nearly pure ore, the magnetite forms a continuous network enclosing detached grains of pyroxene in the same manner as the metallic portion of a meteorite of the mesosiderite type encloses the silicate portions. The annexed figure from a microphotograph of a section of Jacupiranga ore represents this structure. In one place a layer about 15 centimeters thick of pure magnetite containing pyroxene (in part altered to mica) only in a thickness of a few millimeters at the upper and lower surfaces, was seen *in*

* This wholesale passage of pyroxene to mica through weathering is a capital feature in the geology of the two districts and has been very carefully verified. It is not confined to any particular kind of pyroxene as it has been noted also in acmite-bearing rocks and in the pyroxene rocks associated with marble beds.

situ intercalated in schist in which the pyroxene predominates over the magnetite.

At other points flaggy layers were found in which a white element is equally abundant with the pyroxene. This in well preserved specimens proves to be nepheline and the rock standing alone might be called a schistose nephelinite. In this type the iron minerals are rare, while perofskite, apatite, and primary biotite are constant, olivine a frequent accessory.

The peculiar rock above described might very properly be called a pyroxenite if it were not for the objection that this would add still another to the very heterogeneous (as regards geological relations) reunion of types to which that name has been applied.* In view of the evident necessity of subdividing according to geological origin, the so-called pyroxenites, it seems necessary to distinguish this by a distinct name, and it will here be called *jacupirangite*. The rocks included under this title are allied to the nepheline-bearing series and present the various types of pure magnetite, magnetite with accessory pyroxene, pyroxene with accessory magnetite, and pyroxene and nepheline with biotite and olivine as accessory or (in the case of the former at least) essential elements. All these types are most intimately associated as parts of the same mass and the gradual passage from one to the other has been most satisfactorily proven. The most constant and characteristic element is a violet titaniferous pyroxene. Another type of pyroxene-nepheline rock (nephelinite) characterized by green pyroxene and abundant biotite occurs in the district, but has only been seen rarely in loose masses and is presumed to come from dykes and to have an intimate relation to the jacupirangite. At Ipanema a rock of similar mineralogical composition cuts the Carboniferous strata.

The relations of the jacupirangite to the other rocks of the district are not clear. The nepheline-bearing varieties are suggestive of an eruptive origin and the phenomena observed about a long narrow ridge of limestone of presumed Cambrian age, that rises near the center of the jacupirangite area, appear to confirm this suggestion, although no actual contact could be observed. The limestone is a white, coarsely crystalline marble, heavily charged in places with crystals of magnetite and

The mica shows the optical properties of biotite but chemically (at least in the decomposed state in which it could be obtained for analysis), it is essentially a hydrated silicate of iron and alumina.

* In Brazil alone three or four distinct groups of pyroxenite have been recognized. Aside from the one here described, there is one associated with the limestone of the Cambrian (?) series and undoubtedly derived from it through metamorphism. Another is similarly associated with limestones of the gneiss series and still another forms dykes in gneiss. The calcareous groups are rich in scapolite and apparently correspond with a part of the pyroxenites of Barrois and Lacroix, but none agree with the original type as established by Dana for rocks on the Hudson, whose genetic relations seem to be with the peridotites or norites.

apatite. In an opening close to the supposed contact the jacupirangite (profoundly decomposed) is of much coarser texture than is ordinarily the case, with large perfect crystals and crystalline groups of magnetite, an unusual amount of apatite, and large flakes of hydrated biotite with perfect crystalline outlines that appear to form a primary constituent of the rock. The limestone in the neighborhood of the contact contains orthite, which is found abundantly in beautiful microscopic crystals in the sands of the streams flowing from the limestone ridge, but has not been met with elsewhere. At the margin of the area a small isolated hill of Cambrian (?) schists and eruptive rocks of a different type is partially surrounded by jacupirangite, but the contact zone is occupied by swamps. In the saw-mill pit small dykes of foyaite (nepheline-syenite) are seen cutting the jacupirangite which, near the contact, shows large mica flakes as at the supposed limestone contact.

At Ipanema an ore pit in what is presumed to be decomposed jacupirangite shows clearly the eruptive origin of the iron-bearing rock at this place, since it presents a well characterized dyke margin against decomposed schist and, for a distance of a few meters from this margin, a well defined breccia

character due to the inclusion of irregular angular fragments of the schist, as shown in the annexed reproduction of a photograph, in which the lighter colored schist fragments are seen scattered helter-skelter in the dark iron-bearing rock. The

latter is, for the most part, a granular mixture of small irregular grains (often perfect crystals in the leaner ores) of magnetite and decomposed mica, that passes abruptly to a micaceous clay almost free from iron. In this, as in general appearance, abundant residue of apatite and other particulars, it agrees with the decomposed rock of Jacupiranga, the only noticeable differences being in the less apparent schistosity and absence of perofskite.* Unfortunately no sound rock of this type could be found at Ipanema, but in view of the similarity in the decomposition products, the close correspondence in the eruptive rocks of other types in the two districts and the lack of any primary mica-magnetite type to which the Ipanema rock can be referred, it seems quite safe to consider the latter as decomposed jacupirangite and to conclude for the eruptive origin at both localities.

The above described mode of occurrence is the only one that has been observed in the Jacupiranga district. At Ipanema on the contrary only a small portion of the ore in sight can be referred to the Jacupirangite type of rock. The greater part occurs as a superficial drift-like deposit resting (where the underlying rock has been seen, in the extension of about 100 meters) on micaceous clay which according to all the indications results from the decomposition *in situ* jacupirangite free from iron. The ore masses are rounded as if water-worn and vary in size from shot-like grains to blocks of half a cubic meter or more. These for the most part differ in aspect from the jacupirangite ores and, when impure, contain, instead of decomposed mica, nests of granular apatite and masses of secondary silica (chalcedony, quartz and rarely tridymite). Large rounded bowlders of secondary silica with or without inclusions of ore are abundant. In these the only recognizable minerals, aside from the magnetite, are decomposed mica, rare prisms of green pyroxene (acmite) and exceedingly fresh enstatite in large grains much invaded by chalcedony. It is evident from the inspection of the blocks of this superficial deposit that, with the exception of a small part that can be referred satisfactorily to the jacupirangite type, the magnetite occurs as segregations in a rock extremely subject to alteration with separation of secondary silica. This rock contained magnetite, apatite and acmite as primary constituents without original free silica. Whether the mica and enstatite are primary constituents or not could not be determined, but it is strongly suspected that they are not. In this case it may be surmised that they point to original pyroxene and a magnesium silicate probably olivine.

* This is in accord with the general character of the ores, that of Ipanema being a pure magnetite, while that of jacupiranga is highly titaniferous.

An abandoned working badly obscured by forest shows the ore masses *in situ* as rounded aggregates in soft decomposed material which higher up the hill in the natural exposures is charged with secondary silica giving the siliceous masses above described. The whole evidently forms a dyke some ten meters or more in width cutting the Cambrian (?) schists. In the soft material only decomposed mica (perhaps original biotite) could be recognized. A washing gave an extraordinary abundance of apatite and rare prisms of acmite. A loose block with schistose structure consisting of a finely granular mixture of apatite and acmite (the latter showing micaceous decomposition) serves to connect this cutting with another in the vicinity.

A small dyke about 20 centimeters wide and about 100 meters distant from the one above described has afforded specimens in which the original rock-type can be recognized. It consists almost exclusively of orthoclase with some large crystals porphyritically developed in a fine grained holocrystalline ground-mass with rare prisms of acmite and is thus a typical augite-syenite.* Lower down the hill and apparently coming from the same or a similar dyke are some large partially decomposed, partially reconstructed (with secondary silica) blocks of extreme interest. The soft material and the totally reconstructed (with quartz, chalcedony and tridymite) portions closely resemble those of the old mine above described and the latter also contain enstatite. In other portions in which the orthoclase is partially preserved in a kaolinized state the introduction of secondary quartz gives the aspect of an ordinary granite. The acmite is in great part transformed to amphibole and finally to mica. It varies greatly in abundance becoming in places the predominant element and with its increase, apatite substitutes in great part, or wholly, the feldspathic element giving a rock composed entirely of pyroxene and apatite. There is thus at this place an intimate association of three apparently distinct types, viz: an orthoclase-pyroxene rock with predominant feldspar, an orthoclase-apatite-pyroxene and an apatite-pyroxene rock. These last two give on decomposition an apatite-mica rock.

A large road cutting on the opposite side of the ravine and nearly in front of the locality last described is in totally decomposed schistose material in highly inclined layers. The predominant rock is a pyroxene-apatite schist in which the pyroxene (acmite) has, except in a few points, been wholly altered to mica. Through this run narrow dyke-like streaks (particularizations?) relatively poor in apatite in which the

* The daily increasing importance, wide range of variation and peculiar character of the orthoclase-pyroxene combination seems to demand a simple non-committal term as a generic title for so-called augite-syenite group and Brögger's name *Laurvikite* is here employed in that sense.

white element appears to have been feldspar. This resembles the decomposed schist fragments contained in the ore breccia and like them is characterized by an abundance of zircons of peculiar type. In the midst of these schists appear irregular bands and patches (dykes?) of purely micaceous material exactly resembling the iron-free portions of the eruptive rock of the breccia and like it enclosing fragments of schist. The mica-apatite schists also contain several streaks of a much whiter more compact material that look exceedingly like dykes but may perhaps be particularizations. In these mica and apatite are the only recognizable constituents, but it is tolerably certain that a large part of their mass was originally feldspar. One of these streaks about 5^{cm} wide has a central line of rounded aggregates, the size of a walnut, of magnetite and apatite exactly resembling, on a small scale, the bowlders of the superficial ore deposit and the aggregates of the large dyke (p. 12). Large blocks of magnetite scattered about the neighborhood of the cutting indicate that larger aggregates occur though none were seen *in situ*. This little dyke or streak shows that considerable aggregates of magnetite do actually occur in a rock which is presumably a phase of laurvikite and thus permit the reference to that type of the large decomposed dyke with its workable ore bodies.

The decomposed schist of the ore breccia gives on washing an abundant slime of mica flakes and kaolin with a residue of microscopic zircons* of peculiar type and rare grains of undecomposed orthoclase and aconite thus indicating an original orthoclase-pyroxene rock. Just such a rock, characterized by the same peculiar type of zircons, is found in a sound state in the schist hill (Morro de Area Preta)† at Jacupiranga mentioned on p. 800. It here cuts across and is insinuated between the layers of an ordinary metamorphosed Cambrian (?) schist containing quartz, mica, tourmaline and staurolite, in such a manner as to form an extremely curious complex of regular alternating layers, often only a few millimeters thick, of eruptive and rudimentary material. This schistose phase of laurvikite occurs again in a low ridge at a place called Modesto a kilometer or so above the Morro de Area Preta, but here it is itself included in a breccia of which the matrix is the pyroxene-apatite (with subordinate orthoclase) phase of the same rock similar to that already described from Ipanema.

Indications of the genetic relations and geological age of this last phase are afforded by a cutting on the tramway at Ipanema

* These are complicated crystals of the Miask type in strong contrast with the simple prismatic forms found in many scores of washings from the ordinary feldspathic rocks such as gneiss, mica schist, granite, syenite, foyaite, phonolite, diorite, etc.

† Black Sand Hill from the abundance of magnetite in the stream at its base.

where a decomposed intrusive sheet of a highly micaceous rock is intercalated in the Carboniferous sandstone and shale. This includes lenticular nodules that have escaped decomposition varying in size from that of an egg to that of a bushel measure. These consist of the orthoclase-pyroxene (with subordinate apatite) and pyroxene-apatite (with subordinate orthoclase) combinations identical in aspect, both macro- and microscopically, with the rocks from the ore locality at the same place and from the Modesto locality at Jacupiranga. At this place, owing to the decomposition of the enclosing rock, no idea can be found of the origin of the nodules which appear like transported blocks. At another point where the rock is better preserved small aggregates of the same nature seen in microscopic slides are evident segregations. The enclosing rock has a porphyritic structure with large phenocrysts of nepheline, apatite, green pyroxene (acmite) and biotite (extremely abundant) in a fine grained ground-mass too much altered for determination. It had thus the structure and aspect of a phonolite although no feldspar could be detected in it* and the biotite is much more abundant than is usual in the ordinary phonolites. In composition it recalls a coarse holocrystalline nephelinite found in loose blocks at Jacupiranga. A comparison is also suggested with some of the rocks from the Azores and Masai Land called acmite-trachyte by Mügge. A rock of this last type with phenocrysts of sanidine brown pyroxene and haüyne in a felt like ground-mass of orthoclase, acmite and possibly nepheline (since the former gelatinizes freely) occurs in considerable masses at Jacupiranga somewhat to the westward of the ore district.

The above observations indicate in the phases of laurvikite here described a genetic relation with nepheline-bearing rocks and a tendency to a schistose structure, and to abrupt changes in mineral composition, especially in the direction of phosphatic and basic segregations, that is found to a greater or less extent in other phases of the same type at various localities in Brazil. Thus, at two points in the Jacupiranga district and at Cabo Frio, a coarse granitoid laurvikite with rare grains of nepheline and abundant biotite is associated with foyaite masses. A fine grained phase of the same type found in considerable bodies in various outlying hills about the Jacupiranga ore district and in a few loose blocks within it, show a tendency to a linear arrangement of the bisilicate elements (pyroxene, hornblende and biotite) that gives a gneissoid aspect to the rock. The same tendency is seen in an angular fragment

* This may be due to decomposition though as the nepheline is still recognizable it seems singular that orthoclase should have been less persistent. In the segregations nepheline is totally excluded and primary biotite is rare.

enclosed in the foyaite of Tingua (the only specimen of laurvikite found at this locality) in which pyroxene and magnetite are linearly arranged.* A small loose block found associated with foyaite at Jacupiranga has large idiomorphic phenocrysts of dark violet pyroxene, full of inclusions and with beautiful zonal structure, embedded in a holocrystalline ground-mass of orthoclase with abundant bisilicates (green pyroxene and biotite) and occasional grains of plagioclase. This rock, which illustrates beautifully the tendency towards a basic type, presents some features that suggest a comparison with certain phases of jacupirangite. The frequent occurrence of olivine as an accessory in rocks of the laurvikite type also points in the same direction and suggests a possible hypothesis to account for the presence of enstatite in some of the Ipanema rocks.†

In this connection it is interesting to note the same tendency to a basic phase in the granitoid, or foyaite, type of nepheline-bearing rocks. At several points in the Jacupiranga district, considerable masses (dykes?) appear of a plagioclase-pyroxene-biotite rock that has been referred to diabase or gabbro by several eminent petrographers to whom they have been submitted. At two points the blocks of this type are mingled with those of foyaite in a manner to suggest a geological connection, while occasionally, as at Cabo Frio, also particularizations of the same type have been observed in the latter rock. Moreover, a diligent search made by Dr. Hussak reveals an occasional grain of nepheline in the plagioclase rock. A rock of similar character with idiomorphic violet pyroxene and an abundance of olivine also contains rare nepheline grains and is referred to the same type‡ as is also a plagioclase-analeime-pyroxene rock identical in all essential particulars with the teschenite of Elgoth, Silesia, that occurs near the river Ribeira at Jaguary. These plagioclase rocks, which may be compared with the theralithes of Montana and the teschenites of various localities, simulate closely the diabases and gabbros, but differ in their genetic relations, from the ordinary types of that family. Various other peculiar types of eruptive rocks abound in the Jacupiranga district, but so far as known they have no

* The quantity of magnetite in this rock would be large for a rock of purely basic type and is extraordinary for one in which orthoclase is the predominant element. It shows the tendency to basic segregations that culminates in the Ipanema on bodies.

† If the enstatite is primary it is extraordinary that a mineral so subject to alteration should be perfectly fresh while all the other elements, except magnetite and apatite, are altered beyond recognition. If secondary it might have been formed from original olivine as suggested above, or possibly from the magnesia of the decomposed pyroxene.

‡ This, with more abundant nepheline, would correspond very closely with the theralithe of Crazy Mts., Montana.

bearing on the magnetic question. For the most part they are of a basaltic character* corresponding to the rocks referred to augitite, limburgite and tephrite (?) that abound in small dykes in every Brazilian locality of foyaite with which they appear to have some genetic connection. One contains leucite, the third occurrence of that mineral noted in Brazil. Small basic dykes, totally decomposed, but apparently of the same character, cut the Carboniferous strata at Ipanema.

Specimens of magnetite ore from various other points in Brazil in the states of São Paulo, Minas Geraes, Sergipe, Parahyba, etc., show inclusions of decomposed mica and apatite that suggest a comparison with the Ipanema and Jacupiranga ores, and perhaps indicate that the mode of occurrence above described may be quite general. In view of the tendency to a schistose structure and transformation into siliceous masses, it may be suggested that possibly some of the jaspery hematites may have had a similar origin.† The only Brazilian magnetite thus far seen that can be definitely determined as having a different origin is from Palmeiras dos Indios in the state of Alagoas. This, which is similar in appearance to the Cumberlandite of Wadsworth, contains plagioclase and augite and is an enrichment of a gabbro.

Art. XXXVIII.—*On Pink Grossularite from Mexico;* by C. F. de Landero.

The occurrence of pink colored garnets at Xalostoc, District of Cuautla, State of Morelos, Mexico, has been known for some years and specimens from there have been preserved in the mineralogical collections of the School of Mines, in the city of Mexico; but the locality had not been properly explored, the specimens obtained being merely from the surface. About the beginning of the year 1890, Prof. Urquiza gave me, in the city of Mexico, some of these specimens, better than those I had formerly seen: in August of the same year I gave a few of them to Mr. William Niven, of New York City, the diligent mineralogical explorer. Mr. Niven was so much pleased

* The exception is the Vergesite described by Rosenbusch (Mik. Phys. Gesteine, 2d ed., p. 820) from material sent by Mr. Bauer from the Serra do Hilario on the divide between the Jacupiranga and Ribeira. This has been traced in a large dyke for over six kilometers.

† While there is no evidence of any dynamo metaphoric action at Ipanema affecting the larger blocks of magnetite, they have suffered the martite alteration to such an extent that several European mineralogists who have examined the ore prefer to call it martite or hematite.

Since the above article was written a dark green spinel (hercynite?) has been found to be an abundant accessory in the Ipanema magnetite.

with the rose-colored crystals, that he proposed to visit the locality; this he accomplished in the early part of January of this year, and succeeded in obtaining excellent specimens of both pink and colorless grossularite. On his return from his trip, he gave me a number of crystals, and since the material was very pure and well suited for chemical work, I decided to analyze it. This I have done in my laboratory, with the assistance of my colleague Prof. R. Prieto.

We selected for the analysis, small, clean, almost transparent fragments of rose-colored crystals. The specific gravity was found, by pycnometer to be 3·516 at 19·8° C. The qualitative analysis proved the presence of silica, alumina, lime, magnesia, and traces of ferric oxide and manganese. Manganese, though probably the coloring matter, is present in so minute quantity, that its reaction with the borax glass could not be obtained, not even by using a fragment of saltpeter to oxydize the glass. Its presence was however ascertained by fusing the powdered mineral with sodium carbonate, a greenish mass being obtained; this was dissolved in water, with the addition of pure nitric acid, and the clear liquid poured over lead peroxide; after a little time the liquor became pale amethyst-colored.

For quantitative analysis 0·870 grams of very pure carefully powdered material were fused with 3 grams of the usual mixture of dry carbonates of potash and soda, in a platinum crucible, over the flame of a gasolene-vapor laboratory lamp (Dangler's); the mass obtained was dissolved slowly, in very dilute hydrochloric acid, and the silica, alumina, iron, lime and magnesia were determined in the usual manner. The amount of the original mineral that was not attacked by the alkaline carbonates was ascertained by treatment of the weighed silica, with ammonic fluoride, weighing the residue left, and approximate calculation of the corresponding weight of the mineral.

The results obtained were the following:

		Per cent.	Atomic Ratio.	
SiO_2	0·3535	40·64	58·92=3·10	
Al_2O_3	0·1868	21·48	18·13	1·
Fe_2O_3	0·0137	1·57	0·86	
CaO	0·3078	35·38	54·98	2·98
MgO	0·0065	0·75	1·62	
MnO, BaO	trace	trace		
Unattacked mineral	0·0015	0·17		
	0·8698	99·99		

The atomic ratio for SiO_2, R_2O_3 and RO is very nearly 3 : 1 : 3, the normal ratio for the minerals belonging to the garnet group. The formula for the analyzed grossularite, may be written: $[Ca, Mg]_3\ [Al_2, Fe_2]\ Si_3O_{12}$.

All the Xalostoc crystals I have seen are rhombic dodecahedrons (*i*); many of them have a tolerably distinct dodecahedral cleavage. Their hardness is 7·5, and their fusibility a little below 3. By fusion before the blowpipe a yellow glass is obtained; before Fletcher's hot blast blowpipe, fusion is accompanied by intense glowing and a white blebby glass is obtained.

Guadalajara, Mexico, February 18th, 1891.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Determination of Vapor-Pressures.*—A new method for determining the vapor-pressures of solutions has been described by Charpy. The solution to be examined is contained in a large test tube, in the upper portion of which a small condensation hygrometer is placed. After allowing the space above the liquid to become saturated with the vapor of the solvent, accelerating the process by reducing the pressure if necessary, the dew point is determined. Knowing the law according to which the vapor-pressure of the solvent varies, the vapor-pressure of the solution at the temperature of the experiment can be readily calculated. The accuracy of the determination is the greater, the less the pressure that is to be measured. One advantage of this method is the fact that it may be applied to solutions which attack mercury and cannot in consequence be introduced into a barometric tube.—*C. R.*, cxi, 102; *J. Chem. Soc.*, lviii, 1364, Dec. 1890. G. F. B.

2. *Vapor-densities at low Temperatures.*—The method of Demuth and Meyer for determining vapor densities below the boiling point,* has been found by Krause and Meyer to be still applicable when in place of hydrogen, other gases such as air, nitrogen or even carbon dioxide, are used to fill the vaporizing bulb. Although the vaporization is then much slower, perfectly accurate results are obtained; as the authors have shown by their determinations of the vapor-density of xylene at 40° below its boiling point and of paranitrotoluene at 33° below, in air and in carbon dioxide. It is preferable to use hydrogen however in all cases where it is practicable. Experiments made by the authors show that the theoretical vapor-density of acetic acid is reached at about 160°; the values obtained steadily diminishing from 2·60—2·67 at 100°, to 2·12—2·18 at 160° and 2·07—2·14 at 190°; the theoretical vapor-density being 2·08. Cahours, using the method of Dumas, reached the theoretical vapor density of acetic acid, only at 250°. Iodine allowed to vaporize at the tempera-

* See this Journal, III, xxxix, 312, April, 1890.

ture of boiling sulphur in presence of a large excess of air, showed no sign of dissociation; although according to Troost, it is dissociated when thus treated under a diminished pressure. An experiment with sulphur itself at this temperature, in an atmosphere of nitrogen, gave a vapor-density corresponding to the formula S_7; but this result is apparently accidental.—*Zeitschr. physikal. Chem.*, vi, 5; *J. Chem. Soc.*, lviii, 1365, Dec. 1890.

G. F. B.

3. *On the Dispersion of Carbon Compounds.*—Measurements of the refractive and dispersive powers of the simple and mixed ethers of the methane series by BARBIER and ROUX show that the dispersive power and the specific dispersive power increase with the molecular mass, but remain practically the same for all isomerides containing the same quantity of carbon. The introduction of CH_2 into the molecule raises the specific molecular dispersive power by about 8·2. In methyl-, ethyl- and propyl-allyl ethers the dispersive power and specific dispersive power remain practically constant and do not increase with the molecular mass. If these ethers are compared with others containing the same number of carbon atoms, it is seen that the dispersive power increases as the proportion of hydrogen decreases. With methyl-, ethyl-, propyl-, isobutyl- and amyl-benzyl ethers, the dispersive power diminishes as the molecular mass increases, but the addition of CH_2 produces a variation in the specific molecular dispersion equal to about 8·2, as in the methane series. In all cases the specific molecular dispersive power of the ethers is equal to the sum of the dispersive powers of the two alcohols from which they are derived, less the dispersive power of the water eliminated.—*C. R.*, cxi, 180; *J. Chem. Soc.*, lviii, 1353, Dec. 1890.

G. F. B.

4. *On the Electrical Properties of Semi-permeable Walls.*—A semi-permeable material, according to OSTWALD, is a material which permits the solvent to pass through it but not the dissolved salt. The permeability of a given material, however, depends not on the nature of the given salt as a whole, but upon the character of each of its ions. Copper ferrocyanide for example is permeable by potassium chloride, because it allows both the potassium and the chlorine ions to pass through it. But it is not permeable by barium chloride because it does not permit the barium to pass, nor by potassium sulphate because it does not allow the passage of the SO_4 ions. If a solution the ions of which cannot pass through a semi-permeable material be electrolyzed, the electrodes being separated by a semi-permeable wall, the latter will itself act as a metallic electrode. In the author's experiments, a U-tube filled with a solution of potassium ferrocyanide and having parchment paper tied over its ends, was used to connect two glasses containing solution of copper sulphate; so that a layer of copper ferrocyanide formed on the paper. After passing a current through the apparatus for a time, metallic copper was found to be deposited on the paper in the glass con-

taining the positive electrode. The fact seems to be that the positively charged copper ions, coming in contact with the film of ferrocyanide through which they cannot pass, give up their charges and are deposited in the metallic state; the negative $FeCy_6$ ions, accumulating on the other side of the film and there giving up an equivalent of negative electricity, are converted into triad ferrocyanide ions. At the other film the potassium ions permeating the copper ferrocyanide film, pass through it and establish electrical equilibrium by uniting with the SO_4 ions of the copper sulphate. The author thus explains Becquerel's observation that when a tube containing copper nitrate solution is placed in a solution of sodium sulphide, a deposit of copper takes place in the interior of the tube. He also shows that many electrophysiological phenomena may be explained in this way, by the action of semi-permeable materials; such for example as the secondary resistance of albumin noticed some years ago by Dubois Reymond.—*Zeitschr. physikal. Chem.*, vi, 71; *J. Chem. Soc.*, lviii, 1354, Dec. 1890. G. F. B.

5. *On Allotropic Silver.*—PRANGE has observed that after preparing, according to the method described by Carey Lea, the allotropic form of silver soluble in water, there remained in the solution a colloidal form in the dissolved state. The behavior of this solution, not only under the action of light but also at increased temperatures, has been studied by him and he finds that a separation of the dissolved silver takes place in both cases. The maximum concentration of the solution observed by the author was 4·75 grams per liter. In order to study the properties of the second modification of silver described by Carey Lea, the method of preparation was so modified as to permit of larger quantities being obtained pure in a short time. Silver nitrate solution was precipitated with ferrous sulphate and sodium citrate, the liquid decanted from the precipitate and the latter dissolved in water. On the addition of ammonium nitrate, the silver separated and was washed with water containing some ammonium nitrate. It was then filtered off, washed with alcohol and dried over sulphuric acid; all these operations being performed in the dark. The silver so prepared is no longer soluble in water. It is not entirely pure silver, though it contains no Ag_4O since on ignition it does not give up oxygen.—*Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 69, Feb., 1891. G. F. B.

6. *The Continuity of Solid and Liquid;* by CARL BARUS (communicated).—Suitably adapting Kopp's well-known specific volume flask in such a way, that by means of a filament of zinc sulphate solution, the reading can be made electrically, at any temperature or pressure whatever, I obtained a method for the full and precise study of the solid-liquid volume thermodynamics. I am thus able to map out the isothermals and isopiestics, the relation of melting point and pressure, the relation of specific volumes at the melting point and pressure, together with some description of the behavior of solid matter in a suite of operations.

Working between 63° and 130°, 0 and 1900 atm., and upon naphthalene, I found that the specific volume of the liquid on the verge of solidification decreases as temperature increases, whereas the specific volume of the solid on the verge of fusion increases as temperature increases, the former variation being clearly much more marked than the latter. Hence if temperature continually increases, these loci tend to coalesce reproducing the essential feature of Andrews's classical diagram, and pointing out the occurrence of a lower or solid-liquid critical temperature in the positive region of several thousand atmospheres and several hundred degrees Centigrade. At this point liquid will pass to solid and solid to liquid without change of specific volume and obviously without volume lag. In my data the initial or stable contours of James Thomson's isothermals are also shown.

Again I found the volume lag to be pronounced in its static character. Hence the relations of solidifying point and pressure and of melting point and pressure are not identical. If a march be made in the direction of decreasing temperature, the prolonged loci tend to intersect in a region of negative external pressure. Beyond this therefore fusion takes place at a greater pressure than solidification. This I interpret as follows: the normal type of fusion changes into the ice type of fusion, through a transi tional type characterized by the zero of volume lag. So far as I can now discern, the position of the transitional type for naphthalene is below 50° C., and at about −1000 atm. It is noteworthy that the normal type is reached from the ice type, in a direction of increasing temperature.

7. *Photoelectricity.*—Prof. G. M. Minchin, at a meeting of the Physical Society, Jan. 16, read a paper on the electromotive force developed by light falling on sensitive plates which were immersed in suitable liquids. The blue end of the spectrum was found to be the most effective. Currents have a photographic effect on the plates, and this action is strictly confined to the parts through which the current has passed. Comparatively strong currents were obtained from plates coated with eosine and gelatine. A Hertz oscillator restored the sensitive state in a cell placed at a distance of 81 feet. An arrangement of 50 cells in series with an electrometer was exhibited, by means of which light falling on the cells could generate sufficient e. m. f. to ring a bell or light an electric lamp.—*Nature*, Feb. 5, 1891, p. 334. J. T.

8. *Photography of Colors.*—According to M. G. Lippmann, the essential conditions for photography in colors by his method are (1) a sensitive film showing no grain; (2) a reflecting surface at the back of this film. Albumin, collodion, and gelatin films sensitized with iodide or bromide of silver, and devoid of grain when microscopically examined, have been employed. Films so prepared have been placed in a hollow dark slide containing mercury. The mercury thus forms a reflecting layer in contact with the sensitive film. The exposure, development, and fixing of the film is done in the ordinary manner, but when the operations

are completed, the colors of the spectrum become visible. The theory of the experiment is very simple. The incident light interferes with the light reflected by the mercury; consequently a series of fringes are formed in the sensitive film, and silver is deposited at places of maximum luminosity of these fringes. The thickness of the films is divided according to the deposits of silver into laminæ whose thicknesses are equal to the interval separating two maxima of light in the fringes—that is, half the wave length of the incident light. These laminæ of metallic silver formed at regular distances from the surface of the film, give rise to the colors seen when the plate is developed and dried. —*Comptus Rendus*, Feb. 2, *Nature*, Feb. 12, 1891, p. 360. J. T.

9. *Pin-hole Photography.*—Lord RAYLEIGH, in a valuable paper on this subject, discusses the subject of the definition obtainable by apertures of various diameters; and shows that a pin hole may replace a lens under certain conditions. To obtain however the definition of a lens of four inches in aperture a focal distance of five miles would be necessary. With an aperture of ·07 of an inch and a focal distance of seven feet a photograph 8× 10 inches was taken of a group of dark trees which gave as much detail as a lens covering the the same plate. Lord Rayleigh finds the following relations, $2r^2 = f\lambda$ in which r is radius of aperture, f is focal distance and λ is wave length of light.—*Phil. Mag.*, Feb. 1891. J. T.

10. *Lectures on the Electromagnet;* by SILVANUS P. THOMPSON. 287 pp. 12mo. New York, 1891. Authorized American edition. (W. J. Johnston Co.).—Modern technical electricity may be said to rest in large measure upon the development of the electromagnet, and hence the importance of this excellent treatise from the able pen of Prof. Thompson. The volume is a small one, and the subject large, but the author has found it possible to present the matter with much fullness and completeness. The history of the electromagnet is given with an account of the early experiments of Sturgeon and Henry, and this is followed by a description of the principles involved in their construction, the various forms applicable to different purposes and their use in the many forms of mechanism in which they form an essential part. The matter was presented in four lectures delivered a little more than a year since before the Society of Arts in London, and hence the form of presentation gains that directness which exists when the speaker comes into immediate contact with his audience.

II. GEOLOGY AND MINERALOGY.

1. *Lake Bonneville;* by GROVE KARL GILBERT. Monographs of the U. S. Geological Survey, volume i, 438 pp. 4to, with 51 plates and a map. Washington, 1890.—Mr. Gilbert's history of Lake Bonneville—the largest of the Quaternary lakes of the Great Basin, of whose area it covered about one-fourth, embracing Great Salt Lake of to-day—is an admirable exposition

of a most interesting period in the geology of the western United States. This is a region characterized, as the author remarks, by a dry climate, interior drainage, and a peculiar mountain system; while its later history includes changes of climate and drainage with volcanic eruption and crustal displacement. All of these points are clearly brought out in the history of Lake Bonneville.

After a discussion of the topographic features of lake shores in general, with respect to the formation of cliffs and terraces by waves and shore currents, and related points, the author goes on to a description of the shores of Lake Bonneville, which, briefly summarized, are as follows: There is first in order of position, the Bonneville shore-line, 1000 feet above the present Great Salt Lake and embracing an area of nearly 20,000 square miles, synchronous through its whole extent; 375 feet below this is the Provo shore-line, the most strongly marked of all, when the lake area was about 13,000 square miles; between the two are the Intermediate shore-lines, while below the Provo, the slopes exhibit lake sediments with occasional shore-lines, and of these the Stansbury is the most prominent. The chronological order of these shore-lines is: (1) Intermediate, (2) Bonneville, (3) Provo, (4) Stansbury. During the period of the formation of the Intermediate embankments the water surface oscillated up and down, finally reaching its highest stage when the Bonneville shore was formed. At the level of the Bonneville shore-line, the lake had an outlet to the north through the Cache valley and Red Rock Pass into the Snake River valley. The sill of this outlet was alluvium, but when washed out to the limestone ledge, 375 feet beneath, the lake was throughout lowered to this level and this marks the position of the Provo shore-line.

A description in detail of the character of the Bonneville beds, is followed by a summary of the history of the basin. Starting from the previous arid period, the first rise of the lake was long continued and was without overflow; during this period a thick and aluminous yellow clay was deposited. Then followed a second rise of 90 feet higher, causing overflow to the north, as stated above, but this was of short duration and resulted only in the deposition of a thin calcareous white marl. As the drying of the lake went on the basin was divided into a dozen independent basins of which that of the Great Salt Lake is the largest. Since 1845 there has been a repeated rise and fall through a range of ten feet, and a very interesting part of this monograph is concerned with the discussion of the character and causes of these later changes. Connected with the changes in the level of the Lake Bonneville, as also with the parallel history of Lake Lahontan is the glaciation in the neighboring mountains, and the facts observed lead to the conclusion that the Pleistocene lakes of the western United States were coincident with the glaciers of the same district and were produced by the same climatic changes. Besides developing the history of the lakes proper, of which this is a brief outline, an account is also given in the closing

chapters of the connected volcanic eruptions, and also of the accompanying changes in continental level, for which the wide-reaching hypothesis is suggested that the disappearance of the lake and the elevation of the center of the basin stand related as cause and effect. A discussion of this subject was given by the author in this Journal in 1886 (vol. xxxi, 284). Like other recent publications by the Geological Survey, Mr. Gilbert's monograph is profusely illustrated with excellent plates, which add much to the clearness of presentation.

2. *First Annual Report of the Geological Survey of Texas*, 1889; E. T. DUMBLE, State Geologist. 410 pp., 8vo, with maps, plates and other illustrations.—This volume opens with "a review of Texas Geology as developed by the work of the Survey," prepared by the Director of the Survey. The rest of the volume consists of the reports of the working geologists. The "preliminary report of the Gulf Tertiary of Texas, by R. A. F. PENROSE, Jr., gives an excellent account of the formations, together with economic notes on the iron ores, building stones, clays and lignites and other mineral resources of this part of the state. A brief description of the Cretaceous rocks of Texas, and their economic uses, by ROBERT T. HILL, follows. The brief statement in this volume is, for the most part, a résumé of the author's extensive observations. W. F. CUMMINGS has two reports, one on the southern border of the Central Coal-field, and the second on the Permian of Texas and its overlying beds. The author dwells at length on the economic geology of the regions, besides giving some account of the formations. The next is a preliminary report on the Coal fields of the Colorado river, by RALPH S. TARR. The author in the course of his survey arrived at important conclusions with regard to the presence of Lower as well as Upper Carboniferous beds. The views of this careful geologist are published also in the "American Geologist" for September, 1890; besides a brief note in vol. xl, of this Journal. W. VON STREERAWITZ has a preliminary statement on the geology of Trans-Pecos, Texas, relating especially to the character of the country and its mineral resources. The last of the reports is by Prof. THEODORE B. COMSTOCK, on the "Central mineral region of Texas," and covers over 150 pages. The Central mineral region of Texas is occupied in part by Archæan rocks, and twenty-five pages of the report are devoted to them. Subdivisions of the Archæan into systems and groups are proposed, but the account shows that a careful and comprehensive study of the region is required to give them authority and we refer for them to the volume. The Paleozoic and overlying rocks of the region are also described and their orographic movements discussed. Notes follow on the metallic and other minerals, and the various economic products of the region.

3. *Geological Survey of Missouri;* A. WINSLOW, State Geologist.—The House, in the Legislature of Missouri, has recently voted to double the original appropriation for the survey of the State. The sum recommended is $40,000 for the year.

4. *Geological Survey of Alabama;* E. A. SMITH, State Geologist.—The Survey of this State has recently issued a Report of 190 pages, on the Cahaba Coal-fields, by JOSEPH SQUIRE, with an appendix on the geology of the valley region adjacent by DR. SMITH. This Report is illustrated by figures in the text, seven plates and a map of the region.

5. *Catalogues of the British Museum;* Part IV, on the Fossil Reptilia and Amphibia in the British Museum, by RICHARD LYDEKKER, published in the summer of 1890, treats of the orders Anomodontia, Ecaudata, Caudata and Labyrinthodontia. Part II, on Fossil Fishes, a volume of 568 pages and 16 plates issued the present year, contains the Acanthodii of the Elasmobranchii, the Holocephali, Astracodermi and part of the Teleostomi. Part I on Fossil Fishes appeared in 1889.

6. *The Fossil Insects of North America;* by Dr. SAMUEL H. SCUDDER, of Cambridge, Mass.—This great work has just been published by Macmillan & Co., in two quarto volumes. Volume I, treats of the Pre-tertiary Insects and contains 35 plates, volume II, of the Tertiary Insects and contains 28 plates. Only one hundred copies are issued, and half of these are already sold. Over eight hundred and fifty species are described and most of them are figured on the lithographic plates.

The descriptions include, with two or three exceptions, all the fossil insects which have ever been described from North America.

7. *Handbuch der Palæontologie herausgegeben* von KARL A. ZITTEL. II. Abtheilung, Palæophytologie; bearbeitet von Prof. W. PH. SCHIMPER und Dr. A. SCHENK. München und Leipzig, 1879–1890.—The 9th and last number of this important volume of Zittel's Handbuch appeared in November, 1890, completing one of the leading contributions of the time to the science of fossil plants. Begun by Schimper in 1879 and continued by Schenk after Schimper's death in 1884, this work presents the best results of scientific research in this difficult branch of paleontology. The arrangement of the work is systematic, not geological, so that it is a botanical rather than a geological treatise, and loses, it must be admitted, much of its value from the latter point of view. Still, horizons are carefully given when known for the forms treated. The plan has been to discuss and illustrate, in the ascending order of the development of plant life, the principal vegetable types that are sufficiently well authenticated to warrant the assumption that they actually lived at the epochs recorded, and thus, by excluding all doubtful forms, to present a solid body of reliable facts bearing upon the past vegetation of the earth. It is gratifying to note that American discoveries have been carefully considered. L. F. W.

8. *Monographie der baltischen Bernsteinbäume;* von H. CONWENTZ. Danzig, 1890. 4°. 151 pp., 18 colored plates.—This handsome volume has the same form and typography as the preceding two on the amber flora, the first elaborated by Göppert

and Menge and published in 1883, the other begun by them but chiefly the work of Dr. Conwentz after their death, appearing in 1886. The present work is preliminary to another in preparation which is to illustrate the occurrence in amber of great numbers of cryptogamic and spore-bearing plants not hitherto treated in any of the books. But the manner in which these forms occur, chiefly as parasites or saprophytes upon or in the tissues of the amber trees, seemed to necessitate a special treatise setting forth the pathological and teratological aspects of the amber flora, and from this treatise we learn that that flora differed radically in this respect from any living flora, and that, in the language of the author "the pathologic was the rule, the normal the exception!" The treatment is in the highest degree elaborate and exhaustive, and too great praise cannot be bestowed upon the unstinted manner in which the Natural History Society of Danzig, supported by the West Prussian Provincial Landtag, has brought out these monographs. L. F. W.

9. *Ueber die Fructification von Bennettites Gibsonianus* Carr.; von H. Grafen zu Solms-Laubach. Botanische Zeitung, vol. xlviii, Leipzig, 1890, col. 789–798; 805–817; 821–833; 843–847, pl. ix, x. Also separate.—In this paper Count Solms has carefully worked over all the material from the Portland beds showing the fructification of cycadean plants, including considerable that was not known to Buckland, Robert Brown, Mantell, Corda and Carruthers at the time they published. The results reached are very important in disproving the view of Nathorst that the supposed fruiting portions are of parasitic origin, and also in showing, contrary to the theory of the Marquis Saporta relative to the progymnospermic nature of the Mesozoic Cycadaceæ, that the fruiting aggregations of Bennettites represent a relatively high type of inflorescence, reminding us rather of certain dicotyledonous types, such as that of the Compositæ or the Monimiaceæ. This interesting result is confirmatory of the law observed in so many other groups that the ancient types of vegetation advanced in their highest expressions far beyond the degree of development presented by the living forms of the same types, so that the latter have to be regarded as survivals of their earlier and not of their later stages. L. F. W.

10. *Die fossile Flora von Schönegg bei Wies in Steiermark;* von Prof. Dr. Constantin Freiherrn von Ettingshausen. I. Theil. Denkschr. d. math.-naturw. Cl. d. k. Akad. d. Wiss. Wien, Bd. LVII, Wien, 1890, 52 pp. 4 pl. Also separate.—Another rich Miocene flora has come to light in Styria to be added to those of Parschlug, Leoben, Gleichenberg, Köflach and Sotzka. The present paper contains the Cryptogams, Gymnosperms, Monocotyledons and Apetalæ, in which groups the author describes over one hundred and fifty species. The number of Cryptogams, amounting to twenty-five, is especially noteworthy, considering their paucity in other similar floras. A large proportion of the forms here enumerated had already been found in

the European Tertiaries, and of these about half occur in the lower Miocene (Oligocene) beds of Sotzka, Sagor, Häring, etc., and a few in the Eocene. L. F. W.

11. *Das australische Florenelement in Europa;* von Dr. CONSTANTIN Freiherrn von ETTINGSHAUSEN. Graz, 1890. 10 pp. 1 pl. 4°.—This is a systematic reply to various recent criticisms, particularly one by the Marquis Saporta, of the view first suggested by the author in 1850, and independently near the same time by Dr. Franz Unger, which afterwards received the sanction of Prof. Oswald Heer, that the Tertiary flora of Europe has a strongly marked Australian facies in the possession of such genera as Eucalyptus, Dryandra, Banksia, Leptomeria, Casuarina, etc. The critics deny the generic identity of these forms, and Baron von Ettingshausen has here selected some of the most striking cases and presented them anew in comparison with the living plants. Some of the cases are undoubtedly sustained, but in that of Dryandra, until something besides leaves are discovered, it will always be possible to consider the specimens as representing the genus Myrica. L. F. W.

12. *Untersuchungen über Ontogenie und Phylogenie der Pflanzen auf paläontologische Grundlage;* von Prof. Dr. CONSTANTIN Freiherrn von ETTINGSHAUSEN und Prof. FRANZ KRAŠAN. Denkschr. d. math.-naturw. Cl. d. k. Akad. d. Wiss. Wien, Bd. LVII, Wien, 1890, 36 pp. 5 pl. Also separate.—This paper follows naturally upon the series by the same authors, completed in 1889, on atavistic forms in living plants, which was preceded in 1880 by Baron Ettingshausen's memoirs on the phylogeny of plants, the whole forming a considerable body of philosophy bearing on plant development. Much of the space is devoted to a genealogical study of the oaks, illustrated by the physiotypic process, and the authors have probably made out some good cases of the actual descent of living European oaks from Tertiary forms, against the views of de Candolle, Gray, and others that they have been introduced by migrations from the north. Much that is said in the latter part of the paper on the probable mode of transition from lower to higher types of vegetation is sound and conservative, but the comparisons between ferns and dicotyledonous leaves would seem to be founded on mere accidental resemblance. The greater variability of the reproductive parts than of leaves, branches and internal structure is very properly insisted upon as an explanation of many of the facts of plant development. L. F. W.

13. *Analysis of Alaska Garnet;* by A. F. KOUNTZE (communicated).—At the suggestion of Professor Wells, I have recently made an analysis of the well-known garnet from Fort Wrangell, Alaska. The crystals, which are dodecahedrons with edges truncated by the planes of the trapezohedron 2-2 (211), occur embedded in mica schist from which they are readily separated; they have been much admired for their almost ideal symmetry, their large size, and fine red color. The analyses are

as follows: they conform closely to the usual formula, 3RO, R_2O_3, $3SiO_2$ and show that this garnet belongs, as was to have been expected, to the almandite or iron-alumina, variety of the species.

	I.	II.	Mean.	Molecular ratio.			
SiO_2	39·31	39·27	39·29	÷ 60 =		·655	3
Al_2O_3	21·73	21·67	21·70	÷102 =		·212	1
Fe_2O_3	tr.	tr.	tr.				
FeO	30·67	30·97	30·82	÷ 72 =	·426		
MgO	5·22	5·30	5·26	÷ 40 =	·130	·613	
CaO	1·95	2·04	1·99	÷ 56 =	·035		3
MnO	1·57	1·46	1·51	÷ 71 =	·022		
	100·45	100·71	100·57				
Sp. grav.	4·095	4·091					

Sheffield Laboratory, March 6, 1891.

III. Botany.

1. *The West American Oaks;* by Professor Edward L. Greene, illustrated from drawings by Mr. George Hansen, part II, San Francisco, 1890, quarto of 31 pages with 13 plates.—The first part of this extended work, already reviewed in these pages by Professor Goodale, appeared nearly two years ago, describing and illustrating more than twenty oaks of the western States, and defining several new species and varieties. As a prefatory note in part ii explains, Mr. James McDonald, through whose liberality the work is being published, became impressed with the desirability of further investigation of the new and doubtful forms described in the first part. Accordingly he generously defrayed such traveling expenses as were necessary to secure further material and information; and Professor Greene spent the summer of 1889 in studying the oaks in various parts of the west and in collecting specimens for illustration. The results of these later observations are embodied in part II and comprise a number of additions and several significant corrections to the material of the first part. Thus *Quercus McDonaldii*, Greene var. *elegantula* Greene, and *Q. Morehus* Kellogg, are now regarded as probable hybrids, while *Q. dumosa* Nutt. var. *polycarpa* Greene appears to have been founded upon an abnormal state of *Q. dumosa*. While no quality in a scientific investigator is more to be desired than perfect frankness in confessing and correcting errors, it cannot but seem that where several such corrections have to be made, so shortly after the appearance of a work, that its publication was premature. Unfortunately some of the descriptions in part ii seem no more likely to be permanent. Thus a new species is described solely from the foliage of sterile shoots. How uncertain and inexpedient such species-making is, will appear from the description itself, a part of which we may quote: "The almost orbicular general outline of the leaf, and its deep, crowded and even imbricated, doubly lobed margin are very striking peculiarities. But these are the leaves of sterile

shoots, and the low trailing shrub which the collector, in his first letter concerning it has spoken of as a "Vine Oak," so far as known bears no other kind. Nevertheless, one may dare to predict that, if the shrub is ever found in a more perfect state, the fruiting branches will exhibit leaves of a less complicated marginal indentation, and perhaps of a somewhat different general outline. In almost all our oaks, vigorous sterile shoots bear leaves far from typical."

Mr. Hansen's plates are better than those of part I by Dr. Kellogg, and give an excellent general idea of foliage and fruit. More attention could with advantage have been given to detail, and unfortunately the shading in some instances fails to give the desired effect of rotundity in the stems and acorns. B. L. R.

2. *On Isoetes lacustris* L.; by J. BRETLAND FARMER, M.A., F.L.S. (Annals of Botany, vol. v, No. xvii, pp. 37–62, pls. v, vi).—In this paper Mr. Farmer presents a series of critical notes upon the anatomy, morphology, development and systematic affinities of the common *Isoetes*. His results are in several instances at variance with those of previous observers, but are substantiated by clear illustrations, which bear every evidence of accuracy; some indeed having been reproduced from photographs. The treatment of the difficult and disputed question of the growth of the root may be mentioned as of special interest. B. L. R.

3. *Studien über die Tribus der Gaertnereen Benth.-Hook.*; by H. SOLEREDER. (Berichte der deutsch. bot. Gesellsch., viii, pp. 70–100).—The tribe of the *Gaertnereae*, as defined by Bentham and Hooker in the *Genera Plantarum*, contains the genera *Gaertnera*, *Pagamea* and *Gardneria*, and is placed in the order of the *Loganiaceæ*. The position of this small group of plants, however, is a matter of considerable doubt, and Baillon in his *Histoire des Plantes* refers these genera to the *Rubiaceæ*, with which they certainly have much in common. Dr. Solereder, seeing here an excellent opportunity to apply the "anatomical method," has made a histological study of the plants in question, with a view to determining more accurately their relationships. As a result of his researches, he concludes that the three genera cannot be classed in a single group nor indeed in the same order. *Gaertnera* and *Pagamea* he would transfer to the *Rubiaceae*, placing them near *Psychotria*, while *Gardneria* is retained among the *Loganiaceae*. The anatomical considerations upon which these conclusions are based are chiefly the presence or absence of phloem in the medullary tissue, and the occurrence of rhaphides. Neither of these features would ordinarily have much weight in classification. Internal bast occurs and fails to appear, not only in plants of the same order but in the species of the same genus, and the same is probably true of rhaphides. Nevertheless in the presence of the strong morphological resemblances of *Gaertnera* and *Pagamea* to the *Psychotriæ* the additional evidence of relationship which has been derived from the microscopic anatomy may have its value. Dr. Solereder in con-

nection with his histological studies has made a thorough examination of the morphological features as well, and has noted the fact, previously overlooked, that the ovary in the two genera just named is not strictly superior, as in the *Loganiaceæ*, but half inferior; a trait of much interest considering their supposed relationship to the *Rubiaceæ*, which have inferior ovaries. B. L. R.

4. *Ueber die Verbreitung der karpotropischen Nutationskrümmungen der Kelch-, Hull-, und ähnlicher Blätter und der Blüthenstiele;* by ANTON HANSGIRG. (Berichte der deutsch. bot. Gesellsch., viii, pp. 345–355.)—By the term carpotropic the author of this paper designates all movements of nutation which, occurring after fertilization in the flower, assist either in the protection of the young fruit or in the dissemination of the seed. These movements resemble to a certain extent other kinds of nutation, such as the nyctitropic movements, which tend to prevent too great loss of warmth by radiation, or the so-called gamotropic nutations, which directly or indirectly further fertilization; but the distinctness of their biological significance, which is at once apparent, justifies their treatment as a separate class of phenomena. The author first considers the cases of carpotropic nutations of the calyx and floral bracts. Such movements are of course confined to those plants in which these organs persist during the development of the fruit. It is by no means the case, however, that all plants with persistent calyx or bracts exhibit phenomena of the kind. As in the occurrence of other varieties of nutation, the carpotropic movements are more or less characteristic of certain groups; but they not infrequently occur, or fail to appear, quite independently of the systematic affinities of the plants. Thus although many species of *Potentilla* and *Fragaria* exhibit such movements in a pronounced form, they appear to be altogether absent in *Waldsteinia*. The first and most readily observed form of carpotropic nutation in calyx and bracts consists in their closing more or less firmly about the young fruit, undoubtedly as protective envelopes. This phenomenon Hansgirg has observed in over 150 genera of the dicotyledons and about 40 of the monocotyledons. In plants with inferior ovaries the surrounding bracts not infrequently close about the fruit, just as the segments of the calyx do in flowers with superior ovaries. Individuals of the same species have sometimes been found to vary in the extent of their carpotropic nutations. In regard to the mechanism by which these movements are brought about, the treatment is brief and provisional. The closing movements of the calyx and bracts which are to be regarded as really carpotropic are, it is stated, the result of hyponastic growth. From these the author distinguishes the purely passive movements by which a calyx, which has been dilated by the expanding corolla, closes again upon the withering of the petals. The subsequent opening of the calyx and bracts (epinastic movement) for the escape of the mature seeds has also been observed in a considerable number of cases, but is not nearly so frequent as the movement of closing.

The instances of carpotropic nutations which have been observed in the pedicels and floral axes, although fewer in number, are much more varied in character than those of the calyx and bracts. To this category Hansgirg refers such movements as tend to place the young fruit in a more protected position, and those which subsequently assist in setting the mature seeds free. As examples of the former mode of carpotropic nutation he cites the plants in which the fruit is brought, by a movement of the supporting peduncle, to rest upon the ground or even buried beneath the surface; and such aquatics as raise their flowers above water but then by a movement or curving of the peduncle draw the young fruit under the surface again. The closing of the umbel in the carrot is regarded as similar in its biological significance, and its subsequent opening is given as an example of the second sort of carpotropic movement, to secure the better dissemination of the seeds. B. L. R.

5. *The Missouri Botanical Garden;* St. Louis, Dec. 1890.—The many botanists interested in the success of the garden and school of botany at St. Louis, founded and endowed by the late Henry Shaw, are indebted to the director for a very neat and attractively illustrated volume upon the progress and condition of these institutions. Considerable space has been devoted to the life and will of Mr. Shaw, to various addresses, and an account of the first annual banquet of the trustees, presenting thus a social rather than a scientific aspect of botany; special interest, however, attaches to the official report of the director, which describes the nature of the courses of instruction that have been given, the extent of the original investigations, and the growth of the collections. Although the report is most modest in its statements, it will be apparent to every reader that the success of the garden and school has been in great measure due to the untiring energy of the director. B. L. R.

IV. Miscellaneous Scientific Intelligence.

1. *Volcano of Kilauea, Hawaii.*—A letter from Rev. E. P. Baker, dated Volcano House, March 4th, stated that the Great South Basin, Halemaumau, contained then three lakes, two besides the previously described Dana Lake, on the west side of the cone. Dana Lake was boiling up in places, and the lava, where liquid, had a flow to the westward. One of the new lakes is to the east of the cone; its condition is much like that of Dana Lake, but the flow is to the eastward. The other is to the south of the cone, and had a flow to the southward. Thus, in each, the movement of the lava is outward or away from the center of the basin.

The Daily Pacific Advertiser of Honolulu, March 12, has a report from Mr. Maby of the Volcano House that on the night preceding the 8th, the cone of Halemaumau disappeared altogether, sinking out of sight, without other great changes in Kilauea. Some light earthquakes had been felt to the south and

southwest, but none at the crater. Halemaumau had again been quietly emptied.

2. *American Association of Chemists.*—The Conference of Chemists held in Philadelphia, Dec. 30th and 31st, 1890, decided in favor of the formation of a national organization. It was resolved also that the Conference should recommend to all existing American Chemical organizations that they call a meeting of their bodies to be held in Washington in connection with the meeting of the American Association for the Advancement of Science for 1891 and that each of these organizations be requested to appoint a committee, or to continue their present committee for the further discussion of this subject.

Further, that this general Conference Committee, be called together at as early a time as practicable before the joint meeting.

It is proposed that the sub-committees shall formulate such modifications of the Constitution of the American Chemical Society as are deemed necessary to adapt it to the requirements of the Association proposed. Also, that the chairmen of these sub-committees shall then, so far as possible, harmonize the views embodied in these reports of their several organizations and shall have printed for presentation at the joint meeting a report, or majority and minority reports, on a Constitution for the proposed Association of American Chemists.

The Chairman of this Conference, with Professors Clarke and Hale, were appointed a committee to select time and place for the meeting of the general Conference Committee.

3. *Audubon Monument.*—A committee with reference to the erection of a monument to the memory of AUDUBON has been appointed by the New York Academy of Sciences, and a design has been prepared, the execution of which, it is estimated, will cost about $10,000. An appeal is made in a circular to the lovers of science in behalf of it, with the hope that the monument may be erected in the fall of 1891. At present the remains of the great naturalist are in Trinity Cemetery, New York City, without a monument over them. Dr. Thomas Egleston is chairman of the committee and Dr. N. L. Britton secretary and treasurer.

Maximum Stresses under concentrated Loads treated graphically by Henry T. Eddy, 100 pp. with a folding plate. New York (D. Van Nostrand Co.—reprinted from the Trans. Amer. Society Civil Engineers).

The Physicians Visiting List (Lindsay & Blakiston's) for 1891. Fortieth year of its publication. Philadelphia (P. Blakiston, Son & Co.) 1891.

OBITUARY.

ALEXANDER WINCHELL.—Prof. Winchell, acting President of the Geological Society of America at its last meeting in December, and President-elect for the year now passing, died on the 19th of February at Ann Arbor, Michigan. He was born Dec. 31st, 1824, in the town of Northeast, Dutchess Co., N. Y., and graduated at the Wesleyan University, at Middletown, Conn.

In 1854 Mr. Winchell accepted the professorship of Physics and Civil Engineering in the State University of Michigan, at

Ann Arbor, and the following year was transferred to that of Geology, Zoology and Botany. From 1873 to 1879 he was first Chancellor of the University at Syracuse, N. Y., and afterward Professor of Geology and the Natural Sciences in the same University and in the Vanderbilt University of Tennessee. In 1879 he returned to Ann Arbor, taking again the chair he had left, and there remained in active service until his decease.

The subjects of Professor Winchell's publications were various; but his scientific investigations were confined to the departments of Geology and Paleontology. In 1859 he was appointed Director of the Geological Survey of the State of Michigan; and in 1860 he sent to the Legislature his "First Biennial Report," which was published in 1861. The survey was soon after suspended in consequence of the civil war. It was resumed under his charge again in 1869, but two years after he resigned the position. He however published, before this and later, occasional papers bearing on the geology of the State and its mineral resources, besides a geological map of Michigan, and also the results of some observations in other States.

During the later years of Professor Winchell's life his geological work was largely among the Archæan rocks, and especially those of Minnesota, in connection with the survey which was in progress under his brother, Prof. N. H. Winchell, and his reports appear in the annual volumes of the survey. These important contributions to Archæan geology are collected in a volume of more than 500 pages issued by him in 1889, entitled "Field Studies of the Archæan Rocks." "A last word with the Huronian" is the title of a paper read by him before the American Geological Society on the 30th of last December. "The Origin of the Earth's features" was another subject on which he wrote at some length; and in 1885 he presented to the American Association for the Advancement of Science a valuable paper on "The sources of trend and crustal surplusage in mountain structures," the substance of which is published in vol. xxx (1885) of this Journal. In 1886 appeared a Geological Text Book under the title of "Geological Studies," or Elements of Geology, which contains many of his personal observations.

Professor N. H. Winchell's tribute to his brother in the American Geologist for March, rightly says: "He was a man of indomitable will, unremitting industry, with an insatiable love for work in his profession; of broad philanthropy, of penetrating reason, of fearless pursuit of the truth; at home in any realm of nature's handiwork,—which he considered permeated with the essence and will of its Creator; a geologist who embraced geology in all its ramifications, ambitious to serve the world by contributing to its fund of advanced knowledge."

Henry Bowman Brady.—Dr. Brady, the eminent British authority on the Foraminifera, died on January 10th. He was born at Gateshead-on-Tyne, February, 1835.

APPENDIX.

ART. XXXIX.—*Restoration of Triceratops;* by O. C. MARSH. (With Plates XV and XVI.)

IN previous numbers of this Journal, the writer has given the principal characters of the gigantic *Ceratopsidæ*, or horned Dinosaurs, from the Laramie, with figures of the more important parts of the skull and skeleton.* The abundant material now available for examination makes it possible to attempt a restoration of one characteristic form, and the result is given in Plate XV. This figure, about one-fortieth of natural size, is reduced from a large outline plate of a memoir on this group, now in preparation by the writer for the United States Geological Survey.

This restoration is mainly based on two specimens. One of these is the type of *Triceratops prorsus*, Marsh, in which the skull, lower jaw, and cervical vertebræ are in remarkable preservation. The other specimen, although somewhat larger, is referred to the same species. It consists of parts of the skull, of vertebræ, the pelvic arch, and nearly all the important limb bones. The remaining portions are mostly taken from other remains found in the same horizon and localities, and at present are not to be distinguished specifically from the two specimens above mentioned. The skull as here represented corresponds in scale to the skeleton of the larger individual.

In this restoration, the animal is represented as walking, and the enormous head is in a position adapted to that motion. The

* This Journal (3), vol. xxxvi, p. 477, December, 1888; vol. xxxvii, p. 334, April, 1889; vol. xxxviii, p. 173, August, 1889, p. 501, December, 1889; vol. xxxix, p. 81, January, 1890, p. 418, May, 1890; and vol. xli, p. 167, February, 1891.

massive fore limbs, proportionally the largest in any known Dinosaur, correspond to the head, and indicate slow locomotion on all four feet.

The skull is, of course, without its strong horny covering on the beak, horn-cores, and posterior crest, and hence appears much smaller than in life. The neck seems short, but the first six cervical vertebræ are entirely concealed by the crest of the skull, which in its complete armature would extend over one or two vertebræ more. The posterior dorsals with their double headed ribs continue back to the sacrum itself, there being no true lumbars, although two vertebræ, apparently once lumbars, are now sacrals, as their transverse processes meet the ilia, and their centra are coössified with the true sacrum. The four original sacral vertebræ have their neural spines fused into a single plate, while the posterior sacrals, once caudals, have separate spines directed backward.

No attempt is made, in this restoration, to represent the dermal armor of the body, although in life the latter was more or less protected. Various spines, bosses, and plates, indicating such dermal armature, have been found with remains of this group, but the exact position of these specimens can, at present, be only a matter of conjecture.

This restoration gives a correct idea of the general proportions of the entire skeleton in the genus *Triceratops*. The size, in life, would be about twenty-five feet in length, and ten feet in height. The genus *Ceratops* so far as at present known is represented by individuals of smaller size, and in some instances, at least, of quite different proportions. A third genus, which may be called *Sterrholophus*, can be readily distinguished from the other two by the parietal crest, which had its entire posterior surface covered with the ligaments and muscles supporting the head. In *Ceratops* and *Triceratops*, a wide margin of this surface was free, and protected by a thick, horny covering. The type of the new genus is the specimen described and figured by the writer, as *Triceratops flabellatus*, which in future may be known as *Sterrholophus flabellatus*, Marsh. There is some evidence that other forms, quite distinct, left their remains in essentially the same horizon of the Laramie, but their true relation to the above genera cannot be settled without further discoveries.

This group so far as at present investigated is very distinct from all other known Dinosaurs, and whether it should be regarded as a family, *Ceratopsidæ*, as first described by the writer, or as a sub-order, *Ceratopsia*, as later defined by him, will depend upon the interpretation and value of the peculiar characters manifested in its typical forms.

The main characters which separate the group from all other known families of the *Dinosauria* are as follows:

(1) A rostral bone, forming a sharp, cutting beak.
(2) The skull surmounted by massive horn-cores.
(3) The expanded parietal crest, with its marginal armature.
(4) A pineal foramen.
(5) The teeth with two distinct roots.
(6) The anterior cervical vertebræ coössified with each other.
(7) The dorsal vertebræ supporting, on the diapophysis, both the head and tubercle of the rib.
(8) The lumbar vertebræ wanting.

The animals of this group were all herbivorous, and their food was probably the soft succulent vegetation that flourished during the Cretaceous period. The remains here figured are from the Ceratops beds of the Laramie, and were found by Mr. J. B. Hatcher, in Wyoming, on the eastern slope of the Rocky Mountains.

Restoration of Brontosaurus.

On Plate XVI is a restoration, one-ninetieth natural size, of another large Dinosaur, the gigantic *Brontosaurus* of the Jurassic. This differs so widely from *Triceratops* of the Cretaceous that a comparison of the two is most instructive. Each represents the dominant reptilian type of the period in which it lived, and each belongs to a distinct order of the *Dinosauria*. The older form, *Brontosaurus*, was more than double the size of the later *Triceratops*. The former represents a more primitive type, and the latter, one highly specialized. Both show the early character of locomotion on all four feet, which many allied forms of each appear to have nearly or quite lost before their extinction.

In the restoration of *Brontosaurus*, the diminutive head will first attract attention, as it is smaller in proportion to the body than in any reptile hitherto known. The neck was very long and flexible. The body was rather short. The legs and feet were massive, and the bones all solid. The tail was very long and powerful. The animal during life must have been nearly sixty feet in length, and about fifteen feet in height. Its probable weight was more than twenty tons.

Brontosaurus was herbivorous in habit, and its food was probably aquatic plants or other succulent vegetation. The skeleton here represented was found in the Atlantosaurus beds of the upper Jurassic, in Wyoming, west of the Rocky Mountain range.

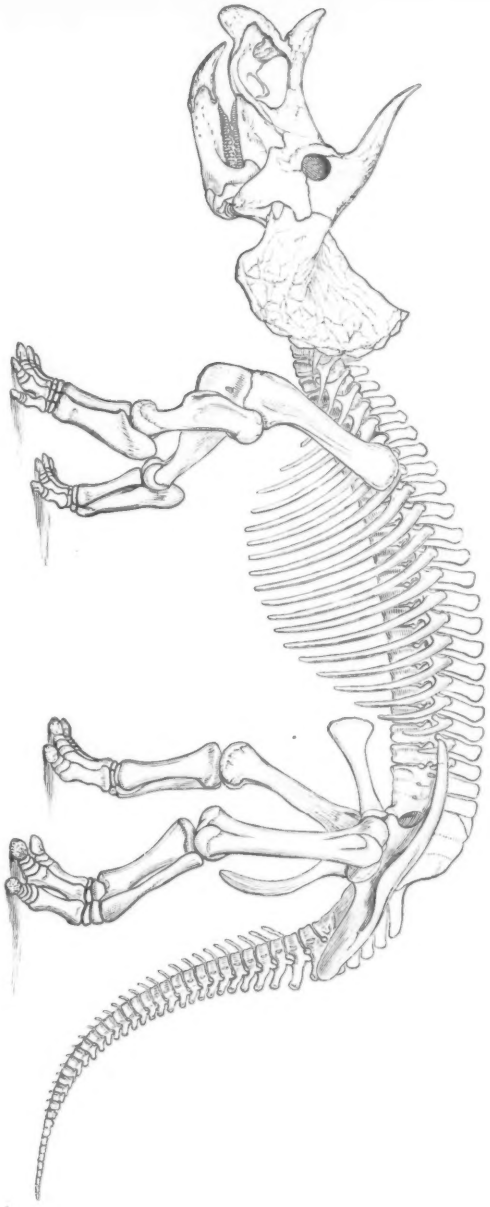
The figure on Plate XVI, one-ninetieth natural size, is reduced from a large restoration, one-twenty-fourth natural size, on a lithographic plate accompanying the monograph of the *Sauropoda*, prepared by the writer for the U. S. Geological Survey. In previous numbers of this Journal will be found various papers by the writer on this group of Dinosauria, and among them, published in August, 1883, is a preliminary outline sketch of the present restoration.

New Haven, Conn., March 18th, 1891.

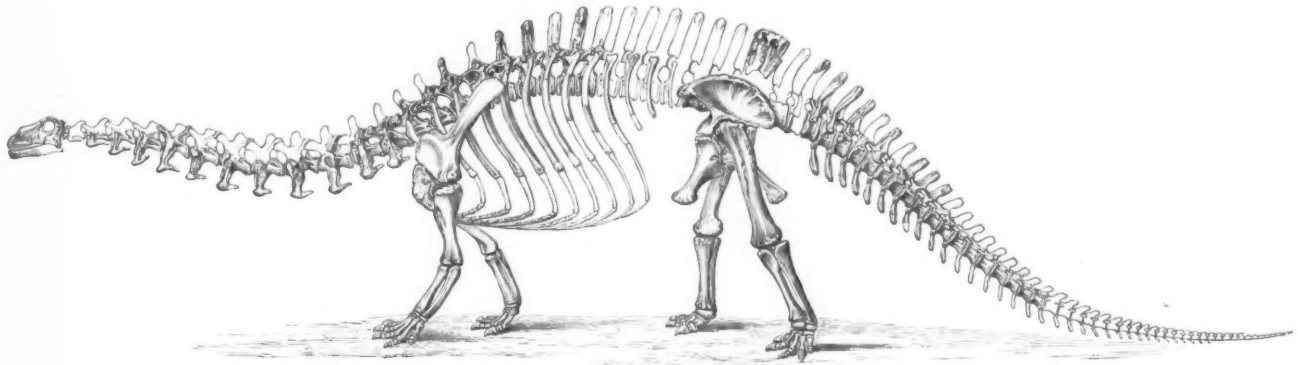
EXPLANATION OF PLATES.

Plate XV.—Restoration of *Triceratops prorsus*, Marsh; one-fortieth natural size. (Cretaceous.)

Plate XVI.—Restoration of *Brontosaurus excelsus*, Marsh; one-ninetieth natural size. (Jurassic.)



Restoration of TRICERATOPS PRORSUS, Marsh. One-fortieth natural size.



Restoration of BRONTOSAURUS EXCELSUS, Marsh. One-ninetieth natural size.

Am. Jour. Sci., Vol XLI, 1891.

ART. XL. — *Development of the Brachiopoda.* Part I. Introduction; by CHARLES E. BEECHER, Ph.D. (With Plate XVII.)

THE Brachiopoda have been so carefully studied, that any new general conclusions regarding them must naturally be based upon features not heretofore considered. In other classes of animals, such important results have recently been reached by the application of the law of morphogenesis as defined by Hyatt, that the writer was led to study the Brachiopoda from this standpoint. The facts observed by this method are mainly new to the class, and considerably affect the taxonomic positions and affinities of the various families and genera.

The value of the stages of growth and decline in work relating to phylogeny and classification is now generally admitted. The memoirs of Hyatt, Jackson, and others, amply show that the clearest and simplest understanding of a group may thus be reached. The application of the principles of growth, acceleration of development, and mechanical genesis, form the main factors in the studies here made. The geologic sequence of genera and species in this connection is also of the greatest importance, for in this way the development of ancient species may be studied, which in their adult condition represent nealogic or nepionic stages of later forms.

The prolific development of the Brachiopoda, both in point of numbers and variety of genera and species, together with their geological history, mark this group as one which should furnish important data for the study of its genesis and of the limits of a specialized variation in a single class. Moreover, as its culmination was reached in paleozoic time, the group should afford illustration of many principles of evolution.

The main characters common to the class of Brachiopoda are as follows: the bivalve shell; the pedicled or fixed condition; the animal composed of two pallial membranes intimately related to the shell; a visceral sac; and two arms or appendages near the mouth. The extreme range of variation does not eliminate any of these features, and, consequently, no univalve or multivalve forms are found, nor any strictly free swimming species, nor growths or modifications adapting the organism to a pelagic life. Thus, the limits of modification are narrowly restricted as compared with those of several other classes, i. e. the Echinodermata and the Pelecypoda, but the thousands of known species of Brachiopoda show what differentiation has taken place within these limits.

The Protegulum.

The first important observation to be noted is, that all brachiopods, so far as studied by the writer, have a common form of embryonic shell, which may be termed the *protegulum.** The protegulum is semicircular or semielliptical in outline, with a straight or arcuate hinge line, and no hinge area. A slight posterior gaping is produced by the pedicle valve being usually more convex than the brachial. The modifications noted are apparently due to accelerated growth, by which characters primarily nealogic become so advanced in the development of the individual as to be impressed finally upon the embryonic shell. This feature is well shown in the development of Orbiculoidea and Discinisca, and is reserved for discussion under these genera.

As the protegulum has been observed in about forty genera† representing nearly all the leading families of the class, its general presence may be safely assumed. In size it varies in different genera and species. The range is from ·05 to ·60^{mm}. A similar range in the prodissoconch of pelecypods has been noticed by Dr. Robert T. Jackson. The protoconch of cephalopods and gastropods also varies greatly. In all these classes, the size of the initial shell has no special relation to the mature form, and it seems to have little significance in related genera or species.

The structure of the protegulum has been described as corneous and imperforate. In all probability it is the same for the entire class, whether among the corneous and phosphatic linguloids and discinoids, or the terebratuloids and other forms having carbonate of calcium shells. Professor E. S. Morse, in describing the early stages of Terebratulina,‡ says: "A heart-shaped corneous shell is formed even at this early stage, for in several cases I met with it where the softer portions had been removed by Paramæcia." Similarly, in the genus Cistella according to Kowalevski:§ "En même temps la coquille se forme, par suite du dépôt sur la cuticule chitineuse des minces couches de calcaire, dans lesquelles on ne voit point encore les perforations tubulaire." Previous to this stage,

* From $\pi\rho\acute{\omega}$, early, and $\tau\acute{\epsilon}\gamma o\varsigma$, a covering.

† Atretia (Cryptopora), Chonetes, Cistella, Conotreta, Crania, Craniella, Discina, Discinisca, Glottidia, Gwynia, Kraussina (Megerlina), Laqueus, Leptæna, Lingula, Lingulops, Linnarssonia, Liothyrina, Magellania (Macandrevia), Martinia, Muhlfeldtia, Obolus? Œhlertella, Orbiculoidea, Orthis group, Pholidops, Productella, Rhynchonella (Hemithyris), Schizambon, Schizobolus, Schizocrania, Schizotreta, Spirifer, Streptorhynchus (Orthotetes), Stropheodonta, Strophomena, Terebratella, Terebratulina, Thecidium (Lacazella), Trematis, Tropidoleptus, Zygospira.

‡ Embryology of Terebratulina. Mem. Boston Soc. Nat. Hist., vol. ii, p. 257, vide figures 68, 76, pl. viii. 1873.

§ Developpement des Brachiopodes, Kowalevski. Analyse par MM. Œhlert et Deniker, pp. 65, 67. 1883.

"Les lobes du manteau commencent alors à se recouvrir d'une cuticule épaisse et rigide que ne leur permet plus de se mouvoir que dans le sens vertical."

From the minuteness and the tenuous nature of the protegulum, its fossil preservation in an unaltered condition would not be anticipated. Neither would it be found on the beaks of mature shells, whether recent or fossil. In rare cases of unusually perfect conservation of the beaks, the protegulum is retained, but frequently its form and characters are exhibited after its removal, by the impression left in the surrounding calcareous test. To study the features of the protegulum, and the early stages in the growth of the shell, it is very desirable and often necessary to have young and well-preserved specimens. The rapid encroachment of the pedicle on the ventral beak commonly obliterates, at an early period, all traces of the protegulum and early nepionic stages. While in the brachial valve, abrasion from foreign objects, or against the deltidial covering, or the pedicle itself, usually removes all early lines of growth or nepionic characters. In general, fully matured shells, recent or fossil, do not furnish material for a study of the incipient growth stages.

Affinities.—In looking for a prototype preserving throughout its development the main features of the protegulum, and showing no separate or distinct stages of growth, the early primordial form hitherto known as Kutorgina, Billings, is at once suggested. This genus, as shown below, includes two distinct types, for one of which the name Paterina is proposed.*

* The strict definition of Kutorgina limits it to calcareous shells, such as are found near Swanton, Vermont, often occurring as casts in the limestone. The original description of *Obolella cingulata* by Billings (Geology of Vermont, vol. ii, p. 948, figs. 347–349, 1861) seems to include two species. One, represented by figures 347 and 349 (loc. cit.), agrees with phosphatic species having a straight hinge line as long as the width of the shell. The other, shown in figure 348, has a calcareous test, shorter hinge, flattened brachial valve, and convex pedicle valve with arching beak. Upon the latter species, the genus was founded, and it has been recognized as the type by C. D. Walcott (Bulletin U. S. Geol Surv., No. 30, p. 102, pl. ix, figs. 1, 1*a*, *b*, 1886.) The species represented by Billings in figures 347 and 349 resembles *Obolus labradoricus* (fig. 345, loc. cit.), and is represented by Walcott (l. c, pl. ix, figs. 2, 2*a*, *b*) and referred by him also to Kutorgina. Mr. Walcott recognizes two groups of species, which are classified (p. 102) as: "shell structure calcareous (*K. cingulata*, *K. Whitfieldi*) or horny (*K. Labradorica*, *K. sculptilis*)."

An examination of specimens representing both groups, leads the writer to consider *Kutorgina cingulata* and *Obolus labradoricus* of Billings as generically distinct. Therefore the name *Paterina* is here proposed to include species of the type of *Obolus labradoricus*. This name is intended to express the primitive ancestral characters which it possesses, Plate XVII, figures 1, 2. Exfoliated specimens of *Paterina labradorica* show a roughened area on the cast, each side of the median line near the beak. These probably represent muscular attachments. Sections of the shell show no hinge area as described in *K. cingulata*. A study of the latter would doubtless present distinct stages of growth. The

The valves of Paterina are subequal, the pedicle valve being a little more elevated than the brachial. They are semielliptical in outline. In mature specimens, all lines of growth, from the nucleal shell to the margin, are unvaryingly parallel and concentric, terminating abruptly at the cardinal line. In other words, no changes occur in the outlines or proportions of the shell during growth, through the nepionic and nealogic stages up to and including the completed ephebolic condition. The resemblance of this form to the protegulum of other brachiopods is very marked and significant, as it represents a mature type having only the common embryonal features of other genera. It is of further importance as representing, in many species, an early condition of nepionic growth subsequent to the protegulum, during which the proportions and features of the shell undergo no modification except increase in size. This is termed the *paterina stage.* It is well shown in the brachial valve of *Orbiculoidea minuta*, Hall, Plate XVII, figure 5.

Modifications from acceleration.—The modifications in the form of the protegulum are due to the influence of accelerated growth, by which nepionic and sometimes nealogic features are pushed forward, or appear earlier in the history of the individual, so as to become impressed upon the early embryonic shell. Only a brief review of these changes will be noted here, as a fuller description properly belongs under the discussions of the various genera and families. Naturally, the greatest departure from the normal protegulum is exhibited in the most variable and specialized valve, the pedicle valve. The nearly equivalve genera, as Lingula and Glottidia, present almost no modification. In the ventral valve of Linnarssonia and Orbiculoidea (Plate XVII, fig. 7), the protegulum has a hinge more or less arcuate. Discinisca shows a subcircular pedicle protegulum with a pedicle notch, and the evidence of any hinge in the brachial is very slight, Plate XVII, figures 8, 9. The discinoid character appearing in the second and third nepionic stage of the paleozoic Orbiculoidea (Plate XVII, fig. 6), has become so accelerated in neozoic and recent Discinisca as to produce a discinoid protegulum.

The strophomenoid shells usually retain a normal protegulum in the brachial valve, but from the acceleration of the discinoid stage in the pedicle valve, the protegulum has an abbreviated hinge and arcuate hinge line, Plate XVII, figures 13, 14, 15.

dissimilar valves, arcuate ventral beak, and mesial depression, could be developed only by passing through several well-marked phases. This in itself seems sufficient for a separation were no other characters present.

No marked variation has yet been observed among the spire bearing genera, nor has any been seen in the terebratuloids or rhynchonelloids further than the radii on the protegulum of Atretia (Cryptopora). Possibly this feature in Atretia is an inheritance from the radiate character of the shell in the Rhynchonellidæ. It may be, however, one of the features consequent upon its fragile nature and deep sea habitat, as observed among other abyssal shells.

Differences in the Valves.

The dissimilarity in the form and relations of the two valves progressively increases in the following genera: Lingula, Terebratulina, Cistella, Discinisca, Thecidium (Lacazella), and Crania. Lingula is nearly equivalve, both valves bearing a close resemblance to each other. In Terebratulina and Cistella, the two valves are more strongly specialized, while in Discinisca, Thecidium, and Crania, they are quite unlike.

Two important organic characters accompany and partake of a similar amount of variation; (*a*) the length and direction of the pedicle, and (*b*) the position and structure of the pedicle opening. Lingula with a long, fleshy, mobile pedicle receives uniformly disposed axial impacts on the valves, and, therefore, with equal physiological reactions, equality in size and form is produced. Terebratulina and most of the other terebratuloids and rhynchonelloids have a shorter and less flexible pedicle. As a whole the motions of the animal are more restricted; the pedicle opening is confined mainly to one valve; the valves, consequently, are differently related to the environment, and express this difference in their dissimilarity. In these examples, also, the inclination of the pedicle to the longitudinal axis, or of the shell to the surface of support, agrees, *pari passu* with the amount of unlikeness in the valves, except when the pedicle is so shortened as to interfere with their free movement. To this inclination is probably due the difference in the action of the forces from without.

Normally, in Lingula, the pedicle is in direct linear continuation with the axis of the shell. Terebratulina and Magellania are inclined at an angle of 40° to the surface of support, but in Cistella and Muhlfeldtia, this is increased to about 70°. In the latter genera, although the position of the axis is nearly vertical, the shortening of the pedicle precludes more than a slight elevation and rotation of the organism. The more the pedicle opening is confined to one valve the greater is the difference between both.

Passing to Discinisca, the pedicle is found to be at right angles to the longitudinal axis, and the valves become strictly an upper and a lower. The lower rests upon the

object of support, and the animal is capable of raising and rotating it only to a slight degree. Under such circumstances, the lower valve is wholly different in its relations to the environment, and, naturally, it expresses the greatest dissimilarity in the two valves of any genus yet discussed. In some allied genera, as Discina (type *D. striata*) and Schizotreta, where the pedicle is small and the lower valve rises above the object of support, a similar form in both valves is again produced by the conical growth of the lower valve.

More primitive types, as Acrotreta and Acrothele, having the plane of the brachial valve at right angles to the direction of the pedicle, retain a marginal upper beak, while the lower is elevated, subcentral, and perforate. These features in Acrotreta and Discina resemble, in a measure, those in the rudistes. In Acrotreta as in Caprotina, the upper valve shows its normal affinities, while the other has become highly modified and dissimilar. But in Discina and Hippurites, the hinge line is lost, and the apex of the upper valve is subcentral. This conical habit of growth in erect attached organisms has been explained as the physiological reaction from equal radial exposure to the environment. It constitutes the law of radial symmetry, ably discussed by Haeckel, Jackson, Korshelt, and Heider. Its application to the Brachiopoda can be made mainly in forms having the pedicle perforation subcentrally located in the lower valve.

In Thecidium and Crania, the calcareous union of the lower valve to the object of support represents the extreme of unlike conditioning, and such forms exhibit the greatest difference in the features of the opposite valves. Crania being probably derived from discinoid stock is without proper hinge. In the history of its development, so far as known, it does not show beyond the protegulum, an early hinged condition. Hence there is no indication of direct derivation from hinged forms. A false hinge is sometimes present, but it clearly shows a secondary mechanical adaptation, and not a phylogenetic character. On the other hand, true hinged attached genera, such as Thecidium (Lacazella), Davidsonia, and Strophalosia, possess this feature as a later ancestral character, and, in their chronological history, tend to shorten and gradually eliminate it. An illustration of this is seen in the succession of the species in Strophalosia, or in the ontogeny of one of the Permian species. *Strophalosia Goldfussi*, in early nealogic stages, has a hinge line about equal to the width of the shell, but in mature individuals, it is usually less than one-half the width. This reduction of the hinge and ostrean form of growth are in accordance with the deductions and observations made upon the Oyster and its allies by Jackson, and the mechanical principles are evidently the same in both cases.

One of the most conspicuous examples of a difference in the form of the valves is shown in the abnormal genus Proboscidella. In early nealogic stages, it resembles an ordinary Productus. Afterwards, probably from burrowing in the mud, the ventral valve becomes extravagantly developed anteriorly into a calcareous tube. This is accomplished by the excessive growth of the anterior and lateral margins. Then an infolding takes place until the lateral edges unite, after which the tube is built up by concentric increment around the free end. The resemblance of Proboscidella to Aspergillum is quite marked, except that, in the latter genus, the tube is formed from the growth and union of two valves instead of one.

From the morphological differences of the pedicle and brachial valves, it will be seen that the highest modifications occur in the former; while the variations in the latter are expressed mainly as adaptive reactions or accommodations to these changes. The explanation of the fact that greater alteration takes place in the pedicle valve evidently lies not in the greater plasticity of this member, but in its more highly specialized and differentiated external form, and mainly in its being the lower and attached valve.

No account is taken here of the crura, loops, and spires of the brachial valve, so characteristic and important in many families and genera. These are evidently processes developed by the internal requirements of the animal and are not affected by the environment. Therefore, they are internal calcified organs independent of the form or manner of growth of the external covering. This is shown by the fact, that, in each group, there is a frequent recurrence of similar general external features, whether in crurate, looped, or spire bearing genera.

Genesis of Form.

The principal characters shared by the two valves are the general outline and the hinge. In typical and generalized forms, as Lingula, Terebratulina, Cistella, and Discinisca, considered as before in regard to length of pedicle, freedom of movement, and direction of longitudinal axis to the object of support, we find a key to these types of structure. In the individual development of Terebratulina, as shown by Morse, we first have the early embryonic shell (protegulum), with a short pedicle and straight hinge. The next stage retains both these characters, but the valves have become more unequal and the pedicle opening confined to the fissure of one valve. The result is a shell very much like Argiope or Megerlia (Megathyris and Muhlfeldtia), to which

Professor Morse also called attention. The same author next showed that the succeeding stage had a comparatively long pedicle, and a shell linguloid in form. Afterwards, the defining of the pedicle opening, shortening of the pedicle and truncation of the ventral beak, produced the final characteristic external features of Terebratulina. The deduction from this example and from Lingula is, that genera having pedicles sufficiently long to admit of freedom of axial movement have elongate and rostrate shells. The shortening of the pedicle brings the posterior part of the shell in more or less close proximity to the object of support, and, as growth cannot take place in that direction, it increases laterally, resulting in broader forms with extended hinge areas, as in many species of Cistella, Scenidium, Muhlfeldtia, Terebratella, Kraussina, etc.

The variety known as *Muhlfeldtia truncata*, var. *monstruosa*, Davidson, further shows how discinoid characters may be produced in an entirely different type of shell. A specimen was found by the writer in a position which readily gave the solution to its variation from the normal species. It was attached to a foreign object under the hinge line of a large mature specimen of *M. truncata*, thus forcing the axis and plane of the valves into parallelism with the object of support. In this way, the pedicle emerged at right angles to the axis. The growth of the shell and the increase in the size of the pedicle caused the latter to encroach on the substance of the lower beak, forming a dorsal perforation or pedicle-notch, which in this example amounted to an arc of 180°. As the ventral valve was the upper and the dorsal the lower, with the pedicle opening through the latter, only the abnormal position of the shell can account for this anomalous discinoid condition. In the development of Orbiculoidea, a true discinoid genus, it will be seen that during the early stages it had a straight hinge and marginal beaks, Plate XVII, figures 5, 6, 7. Then, from its procumbent position and peripheral growth, the pedicle became more and more enclosed by the lower valve, until in Schizotreta (fig. 11) and Acrothele (fig. 12), the opening finally became subcentral.

The resemblance between this form of growth and habit and Anomia is very suggestive. Morse and Jackson have shown, that from an early normal, bivalve, hinged shell, the right valve, in its subsequent growth surrounds the byssus, which occupies much the same position and performs a function similar to the pedicle of Discinisca and Orbiculoidea. Peripheral growth also causes the initial shell to recede from the margin. Another instance is thus furnished of a discinoid habit in an organism otherwise entirely different. It is there-

fore evident, that the discinoid form is purely due to the mechanical conditions of growth. Hence the writer believes, that any bivalve shell with the plane parallel to the object of support, and attached by a more or less flexible, very short organ, as a byssus or a pedicle, without calcareous cementation, assumes a discinoid mode of growth.

The conditions of radial symmetry and ostrean growth were briefly mentioned in a preceding section, and need only be cited here as resulting from the cemented state of fixation, as shown in species of Thecidium, Strophalosia, and Crania.

A long pedicle accompanies elongate shells with short hinges. A short pedicle causes extended hinge growth when the plane of the valves is ascending or vertical, but a discinoid form results when the plane of the valves is horizontal.

Types of pedicle openings.

M. Deslongchamps is one of the few writers who have given much consideration to the characters of the pedicle opening. His studies, although mostly confined to the terebratuloids and later spire bearing genera, conclusively show the importance of this feature.* In a recent paper by the writer,† attention was called to the persistence and embryonic features of this portion of the shell. "It has been shown by J. M. Clarke and the writer, that all species, so far as examined, possessing a true deltidium in the adult state, show that it was gradually developed in early stages of growth, by concrescence along the lateral margins of an open triangular area. Also, that all species furnished with a pedicle-sheath have it fully developed in the earliest growth-stages which have been observed for these species, and the subsequent growth of the individual does not materially alter its general characters, except that it is sometimes retrogressive, the parts becoming atrophied or functionally obsolete. A feature of such importance, and so intimately connected with the embryonal growth of the shell, must be given considerable significance in discussing the various genera in which it is present or absent." At that time, the development and true interpretation of these different features of the pedicle opening and the early stages of the shell had not been studied sufficiently, and a more general application of the principles involved could not then be made. The results of later studies give prominence to these characters, and show that they furnish a method for an ordinal grouping of the genera of brachiopods. This is found to agree with the chronological

* Note sur le développement du deltidium chez les brachiopodes articulés. Bull. Soc. Géol. France. 2e Ser. T. XIX, pp. 409–413, pl. IX, 1862.

† This Journal, vol. xl., p. 217, Sept. 1890.

history of the class, as well as with the anatomical and shell characters, and therefore it is believed to be a natural and reliable subdivision.

The first and simplest type of pedicle opening is in shells with a posterior gaping of the valves, through which the pedicle protrudes in line with the axis. It is shared more or less by both valves, although, generally, the greater portion of the periphery is included by the pedicle valve. The genera Paterina and Lingula afford types of this form of pedicle opening.

The second type is characterized by a pedicle wholly confined to the lower valve, and emerging at right angles to the plane of the valves. In primary forms, it is not entirely surrounded by shell growth, but occupies a sinus, slit, or fissure. A further specialization carries it quite within the periphery, and it finally becomes subcentral. A serial illustration of this type is presented in the genera Schizocrania, Orbiculoidea, Discinisca, Schizotreta and Acrothele. The group probably terminates with forms like Crania and Pholidops, as shown by the development of the brachial valve and from internal characters. The development of the lower valve, however, has not been observed as yet in either of these genera.

The third form is an accelerated derivative of the second. During the first nepionic stage of shell growth, the pedicle is enclosed by the substance of the ventral valve. The perforation remains submarginal, and does not tend to become centralized as in the preceding group. The initial pedicle opening may be maintained by further growth, forming a pseudodeltidium; or it may be merged into the hinge opening by resorption of the shell or by pedicle abrasion. Orthisina, Leptæna, Strophomena, Chonetes, and Stropheodonta furnish illustrations of the first condition, and the second is represented in Tropidoleptus and in the groups of Orthis.

The fourth type in its incipient stage marks a return to the simple conditions of the first, but in early nepionic stages the pedicle is confined to the ventral beak, and deltidial plates are developed in the majority of species. These plates at maturity may entirely limit the pedicle opening below, so that the pedicle emerges immediately under the beak, or encroaches upon the substance of the beak itself. This type of opening is shown by Zygospira, Spirifer, Rhynchonella, Terebratulina, Magelliana, etc.

The only divisions of the class which have had continued existence are the Arthropomata and Lyopomata, proposed by Owen in 1858.* Subsequently, various authors gave names to

* Encycl. Brit., 8th ed., vol. xv, p. 301, 1858.

express other characters, but all included the same elements in the two divisions. Professor Huxley's terms, the Articulata and Inarticulata, have also come into current use, and are convenient to express the nature of the union of the valves. All the names proposed for these divisions by Owen, Bronn, Huxley, Gill, and King, are based upon (1) the intestinal canal whether ending in an anus or in a blind sac, (2) the relative proportions of the viscera and brachia to the shell cavity, and (3) the character of the union of the valves.

If, as Agassiz has said,* orders should be founded upon facts of development or embryology, the ordinal division into groups expressing the genesis of an important common character should furnish a satisfactory classification. The Articulata and Inarticulata do not appear to have a primary developmental basis in nature. These names may be conveniently retained as two divisions or sub-classes, but they fail to express the true relationships of the various groups included in them.

In 1883, Dr. Waagen (Palæontologia Indica) proposed a classification comprising six suborders, founded partly on the pedicle opening and on the form of the brachial supports. Two of his groups, the Mesokaulia and Aphaneropegmata, are nearly equivalent in extent to the Atremata and Protremata now proposed. Daikaulia and Gasteropegmata of Waagen are here included in the Neotremata, and the Telotremata comprise the Kampylopegmata and Helicopegmata of the same author. With the transfer of some genera in his suborders, they may properly be recognized and serve further to differentiate the class into comprehensive groups.

After this preliminary discussion, the four groups proposed can be defined and understood. The special details with full illustration and demonstration of the development and affinities in each group are left for future consideration. At present it is aimed to give only the general results which have been reached through the study of individual development (ontogeny) among various species representing the families of nearly the entire class. Of the sixteen families of Brachiopoda recognized by Œhlert in Fischer's "Manuel de Conchyliologie," fifteen have thus been studied and determined. The genera marked by an asterisk have been examined somewhat in detail. The others have been investigated partly from adult specimens, and from the published descriptions of the genera.

* Methods of Study in Natural History, L. Agassiz. 8th ed., p. 76, 1873.

Atremata.

(*α*, priv., and *τρῆμα*, perforation.)

Plate xvii, figures 1–4.

Protegulum semicircular or semielliptical; hinge line straight or slightly arcuate. Growth taking place mainly around the anterior and lateral margins, never enclosing or surrounding the pedicle, which in all stages emerges freely between the two valves, the opening being more or less shared by both. Valves inarticulate.

Including the genera:

Dignomia.	*Leptobolus.	Obolus.
Dinobolus.	*Lingula	*Paterina.
Elkania.	Lingulasma.	Paterula.
Glossina.	*Lingulops.	Rhynobolus.
*Glottidia.	Monomerella.	Trimerella.
Lakhmina.	Obolella.	

Neotremata.

(*νεός*, young, and *τρῆμα*, perforation.)

Plate xvii, figures 5–12.

Protegulum as in the preceding order in primitive forms, becoming more circular, and with shorter and more arcuate hinge in the pedicle valve of derived types. Growth of the brachial valve tending to become peripheral. In the opposite valve, the pedicle more or less surrounded by progressive nealogic growth posterior to the initial hinge. Pedicle fissure remaining open in primitive mature forms, becoming enclosed in secondary forms during nealogic stages, and in derived types enclosed in early nealogic or nepionic stages. Valves inarticulate.

Including the genera:—

Ancistrocrania.	*Discinopsis.	*Orbiculoidea.
Acrothele.	Helmersenia.	Pseudocrania.
Acrotreta.	Iphidea.	*Rœmerella.
*Conotreta.	Kayserlingia.	*Schizambon.
*Crania.	Lindstrœmella.	*Schizobolus.
*Craniella.	*Linnarssonia.	*Schizocrania.
Craniscus.	Mesotreta.	Siphonotreta.
*Discina.	*Œhlertella.	*Trematis.
*Discinisca.		

Protremata.

(*πρώ*, early, and *τρῆμα*, perforation.)

Plate xvii, figures 13–21.

Protegulum of the brachial valve as in the Atremata. In the pedicle valve, it has become modified through acceleration to an elliptical or circular form with arcuate hinge. Pedicle enclosed in early nepionic stages by shell growth; posterior covering (pseudo-deltidium) retained at maturity, or resorbed or abraded in nealogic stages, so that the pedicle protrudes between the two valves. The stages of growth, in general, represent (1) a paterina stage, with straight hinge line and pedicle opening shared by both valves; (2) a discinoid stage, without straight hinge, pedicle enclosed by concentric peripheral growth of pedicle valve; and (3) a straight hinged condition, with pedicle opening either retained or merged into fissure of hinge area. Valves articulate.

Including the genera:—

Amphigenia.
Aulosteges.
Bactrynium.
Bilobites.
Camarella (group).
Camarophoria.
*Chonetes.
Clitambonites.
Conchidium.
Davidsonella.
Davidsonia.
Daviesiella.
Derbya.
Enteletes.
Eudesella.
Hemipronites.
Hipparionyx.
*Lacazella.
*Leptæna.
Leptænisca.
Lyttonia.
Meekella.
Mimulus.
Oldhamina.
*Orthis (group).
Orthisina.
*Orthotetes.
Pentamerella.
Platystrophia.
*Plectambonites.
Porambonites?
Proboscidella.
*Productella.
Productus.
*Rhipidomella.
Schizophoria.
Sieberella.
Streptis.
*Streptorhynchus.
Stricklandinia.
Strophalosia.
*Stropheodonta.
*Strophomena.
*Strophonella.
Thecidella.
*Thecidium.
Thecidopsis.
Triplecia.
*Tropidoleptus.

Telotremata.

(*τέλος*, last, and *τρῆμα*, perforation.)

Plate xvii, figures 22–28.

Protegulum as in Atremata. Pedicle opening shared by both valves in nepionic stages, usually confined to one valve in later stages, and becoming more or less limited by two deltidial plates in ephebolic stages. Arms supported by calcareous crura, spirals, or loops. Valves articulate.

Including the genera:—

Acanthothyris.
Ambocœlia.
Amphiclina.
*Athyris.
*Atretia (Cryptopora).
*Atrypa.
Bifida.
Bouchardia.
Centronella.
*Cistella.
Clorinda.
*Cœlospira.
Cœnothyris.
Cryptonella.
Cyrtia.
Cyrtina.
Dayia.
Dictyothyris.
Dielasma.
Dimerella.
Disculina.
Eatonia.
Eudesia.
Eumetria.
Glassia.
Grunewaldtia.
*Hemithyris.
Hindella.
Ismenia.
Karpinskya.
Kayseria.
Kingena.
Koninckella.
*Koninckina.
*Kraussina.
*Laqueus.
Leptocœlia.
Liorhynchus.
*Liothyrina.
*Macandrevia.
Magas.
*Magellania.
*Martinia.
Martinopsis.
Megathyris.
Megalanteris.
*Megerlina.
Merista.
*Meristella.
*Meristina.
*Muhlfeldtia.
Nucleospira.
Pentagonia.
Peregrinella.
Platydia.
Rensselæria.
Reticularia.
Retzia.
*Rhynchonella.
Rhynchonellina.
Rhynchoporina.
Rhynchotrema.
*Rhynchotreta.
*Spirifer.
Spiriferina.
Spirigerella.
Stringocephalus.
Suessia.
Syringothyris.
*Terebratella.
Terebratula.
*Terebratulina.
Terebratuloidea.
Thecospira.
Trematospira.
Trigonosemus.
Uncinulus.
Uncites.
Zellania.
*Zygospira.

Yale Museum, New Haven, Conn., March, 21, 1891.

EXPLANATION OF PLATE XVII.

Atremata.

FIGURE 1.—Brachial valve of *Paterina labradorica*, Billings. × 3.

FIGURE 2.—Pedicle valve of young specimen. × 3.
Primordial. *Near Georgia, Vermont.*

FIGURE 3.—Apex of pedicle valve of *Glottidia Audebarti*, Brod. × 25.

FIGURE 4.—The same; brachial valve; showing more distinctly terminal protegulum. × 25. Recent. *Beaufort, North Carolina.*

Neotremata.

FIGURE 5.—Upper valve of nepionic *Orbiculoidea minuta*, Hall; representing protegulum (*p*) and paterina stage. × 25.

FIGURE 6.—More advanced condition; showing acquisition of discinoid characters. × 25.

FIGURE 7.—Lower valve of young specimen; showing protegulum and open pedicle notch. × 25.
Devonian, Marcellus Shale. *Avon, New York.*

FIGURE 8.—Accelerated. discinoid, dorsal protegulum of *Discinisca lævis*, Sowerby, corresponding to nealogic stage of *Orbiculoidea minuta*, figure 6. × 25.

FIGURE 9.—Ventral protegulum of same species similarly modified, agreeing with figure 7. × 25.

FIGURE 10.—Lower valve of same species; showing submarginal position of pedicle opening. Natural size. Recent. *Callao, Peru.*

FIGURE 11.—Lower valve of *Schizotreta tenuilamellata*, Hall; showing centripetal tendency of pedicle opening. Natural size.
Niagara Group. *Hamilton, Ontario.*
(Pal. N. Y. Extract from vol. viii, pl. IVE, fig. 10, 1890.)

FIGURE 12.—Lower valve of *Acrothele subsidua* (after Linnarsson); showing subcentral position of pedicle opening. Natural size.

Protremata.

FIGURE 13.—Dorsal protegulum and early nepionic growth lines of *Plectambonites segmentina*, Angelin. × 80. Upper Silurian. *Gothland, Sweden.*

FIGURE 14.—Dorsal protegulum of *Chonetes scitulus*, Hall. × 80.
Hamilton Group. *Thedford, Ontario.*

FIGURE 15.—Accelerated discinoid ventral protegulum of *Chonetes granuliferus*, Owen; showing pedicle notch. × 80.
Coal Measures. *Manhattan, Kansas.*

FIGURE 16.—Discinoid nepionic stages of ventral valve of *Orthotetes elegans*, Bouch. × 25. Compare with figure 12 of Acrothele.
Devonian. *Ferques, France.*

FIGURE 17.—Nepionic stages of *Stropheodonta perplana*, Conrad; showing pedicle perforation, pseudo-deltidium, and hinge area. × 25.
Hamilton Group. *Falls of the Ohio.*

FIGURE 18.—Ventral nepionic discinoid stage of *Strophomena rhomboidalis*, Wilck. × 25.

FIGURE 19.—Profile of the same. × 25.
Lower Helderberg Group. *Albany County, New York.*

FIGURE 20.—Hinge of a specimen 2^{mm} in length; showing deltidial covering and hinge area.

FIGURE 21.—Ventral view of specimen having same dimensions; showing nepionic and nealogic stages, and relative proportions of pedicle opening and shell at this stage. Niagara Group. *Waldron, Indiana.*
Figures 20 and 21 are taken from "Development of Some Silurian Brachiopoda," Mem. N. Y. State Museum, vol. i, No. 1, pl. II, figs. 2, 12, 1889.

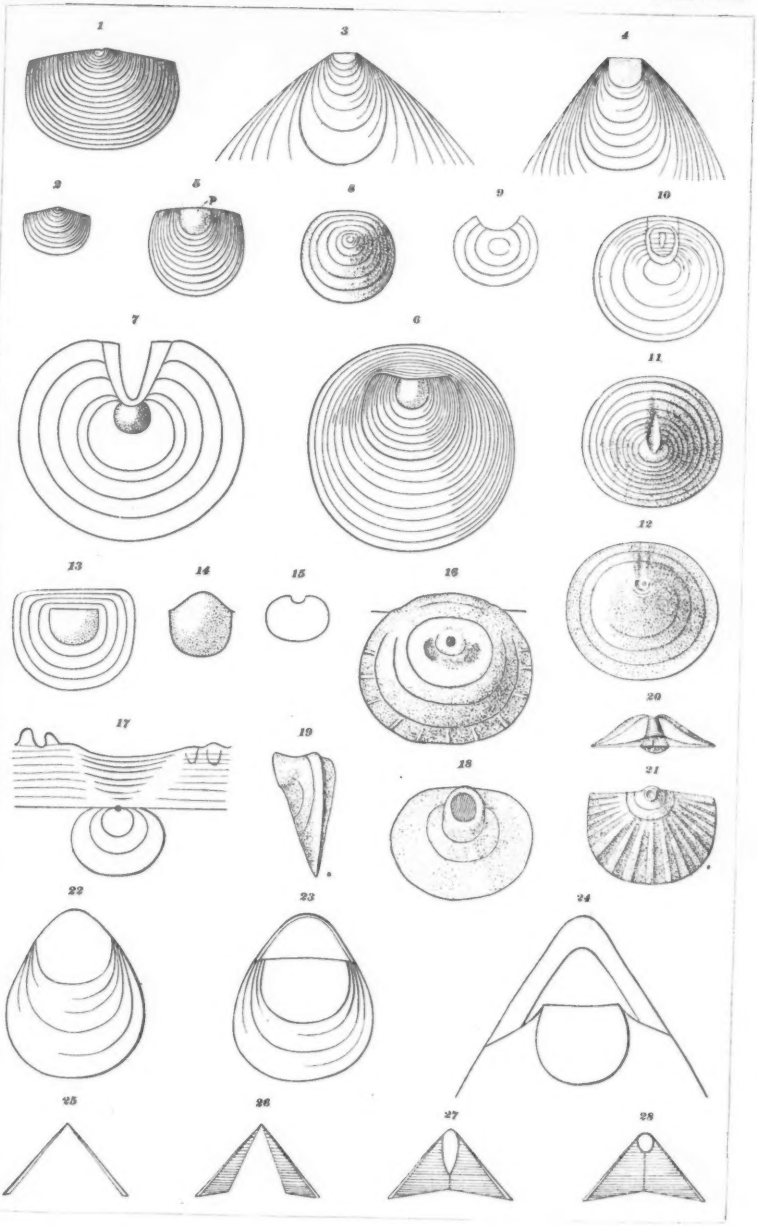
Telotremata.

FIGURE 22.—Ventral view of young *Kraussina* (*Megerlina*) *Lamarckiana*, Davidson; showing protegulum and early nepionic stages. × 80.

FIGURE 23.—Dorsal view of same; showing dorsal protegulum and pedicle opening in ventral valve. × 80. Recent. *Port Jackson, Australia.*

FIGURE 24.—Dorsal view of beaks of young *Terebratulina septentrionalis*, Couthouy; showing dorsal protegulum and pedicle opening in ventral valve. × 80. Recent. *Eastport, Maine.*

FIGURES 25–28.—Diagrammatic representation of ventral areas; showing progressive development of deltidial plates. Figure 25 is without plates, as in ventral area of figure 23. Figure 26 shows two triangular plates, which unite by symphysis in figure 27, making an elongate pedicle opening. In figure 28, pedicle perforation is subcircular and truncates ventral beak. This series corresponds essentially with that shown in *Rhynchotreta cuneata*, Dal., in "Development of Some Silurian Brachiopoda," loc. cit., pl. IV, figs. 16–22.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